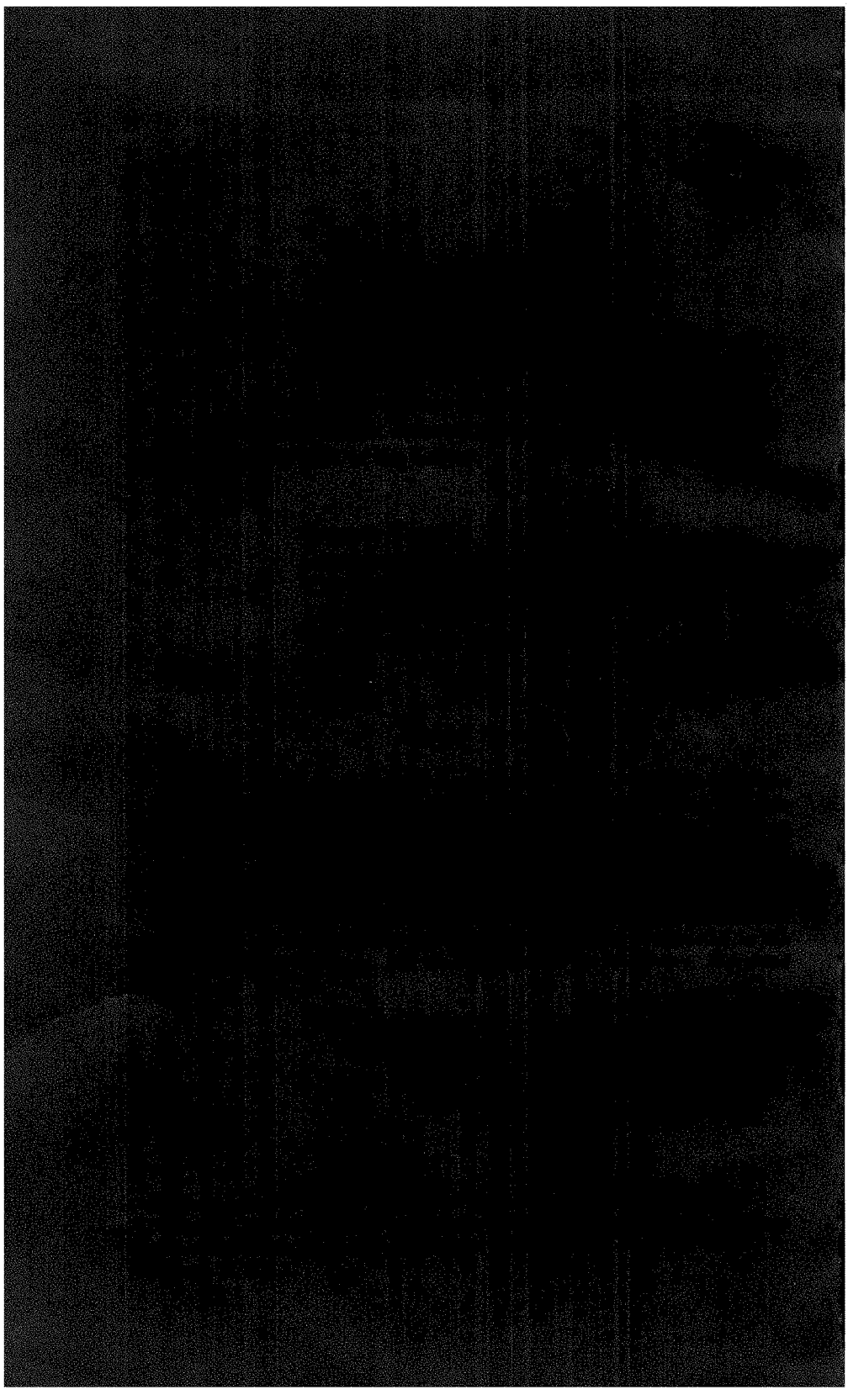
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P 9541

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BULLETIN

OF THE

Operations Research Society of America

Supplement 1 OPERATIONS RESEARCH Volume 16, 1968

Program of the Joint ORSA-TIMS Meeting

REGISTRATION INFORMATION B-2
COMMITTEE FOR THE MEETING B-5
HOTEL FLOOR PLAN B-6
SUMMARY OF EVENTS B-7
INDEX OF PARTICIPANTS B-10
PROGRAM OF THE MEETING B-16
ABSTRACTS OF THE PAPERS B-55

Society Affairs

THE ORSA COUNCIL MEETING B-181
TREASURER'S REPORT B-183

News and Announcements B-186

Supplemental Report—Educational Programs in OR B-195

ORSA/TIMS Joint Meeting

SAN FRANCISCO

REGISTRATION INFORMATION

Registration

The registration desk at the St. Francis Hotel will be open to accommodate preregistered and nonregistered delegates at the following times and locations.

Tuesday, April 30	6:00 PM–12:00 PM	Mezzanine, by Georgian Room
Wednesday, May 1	8:00 AM–5:00 PM	Foyer, Post Street Entrance
Thursday, May 2	8:00 AM–5:00 PM	Foyer, Post Street Entrance
Friday, May 3	8:00 AM–2:00 PM	Foyer, Post Street Entrance

Fees for registration and luncheons are as follows:

Registration:	
Members of ORSA or TIMS	$15.00
Non-members	$20.00*
Full-time students	$3.00
Thursday Luncheon	$5.00
Friday Luncheon (Chinatown)	$5.00

With the exception of certain designated guests and non-member invited speakers, all attendees including speakers, panel members, and session chairmen are expected to register and pay their fees.

Preregistration

The committee strongly recommends preregistration for the meeting and the luncheons, which are space-limited. To do so, mail the enclosed form with your check or money order (do not send cash) payable to "Joint ORSA/TIMS Meeting 1968" to the Registration Chairman: Philip L. Forsyth, Tri Valley Growers, 100 California Street, San Francisco, California 94106.

Accommodations

The St. Francis Hotel has reserved 300 rooms for this meeting, with additional overflow capacity in nearby hotels. Daily rates for the St. Francis are listed on the enclosed hotel reservation form. To reserve a room, mail this form directly to the St. Francis hotel, *not* to the registration chairman.

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* The increment of $5.00 is applicable to membership in either Society; membership desks will be located in the registration areas.

PROGRAM COVER

The program cover was especially designed for the meeting by Wes Wilson. Readers of *Life* magazine will be familar with the work of Mr. Wilson, who is a well-known San Francisco poster artist.

SPECIAL FUNCTIONS

Wednesday evening, May 1, from 6:00 to 8:00 p.m., there will be a no-host cocktail party in the Italian Room of the St. Francis Hotel.

Thursday, May 2, at half past noon, there will be a luncheon in the Colonial Room of the St. Francis Hotel. The President of ORSA, John E. Walsh, will deliver the Retiring Presidential Address.

Friday, May 3, there will be a luncheon at 12:15 p.m. in the Empress of China Ballroom at 838 Grant Avenue in Chinatown. The Empress of China is located in one of Chinatown's new "skyscrapers" and affords an excellent view of the surrounding area. Those so inclined may make the trip to Chinatown on foot—it's a short walk from the St. Francis Hotel. Those exhausted by the sessions may travel to Chinatown by Motorized Cable Car. The Motorized Cable Car Line will leave from the Post Street entrance of the St. Francis Hotel starting at noon. Tickets for the Motorized Cable Car ride will be included with the luncheon ticket. The speaker for the luncheon is Mr. John F. Briggs, Executive Secretary of the Information Systems Committee of the Council of State Governments.

LADIES' PROGRAM

Wives of attendees are cordially invited to attend all sessions as guests of ORSA and TIMS. Also, the Oasis Room on the second floor of the St. Francis Hotel has been set aside as a hospitality suite for ladies staying at the hotel. Coffee and sightseeing information will be available there daily.

The St Francis Hotel faces on Union Square—the center of San Francisco and the heart of the downtown shopping area. The Visitor's Information Center is located at 476 Post Street, just across from the hotel. Guided tour, concert, and theater tickets may be obtained from agencies in the lobby of the hotel.

San Francisco's Powell Street cable car runs directly in front of the hotel. Chinatown and Broadway's famous cabarets are within walking distance. Board a cable car at the hotel's entrance and you are off on a unique tour of San Francisco, headed either for the Fisherman's Wharf district or Ghirardelli (the chocolate factory) Square. The City's famous MUNI system (or, if you prefer, a guided tour bus) takes those so inspired to the Haight-Ashbury flower land.

CLIMATE AND DRESS IN SAN FRANCISCO FOR MAY

In May you will find clear, sunny days and a spring-like crispness to the air; the average maximum temperature of this season is 63.4°, the average minimum 50.8°. Rain is a rarity at this time, but it would be well to prepare for an occasional drizzle, as well as for the chance of a really balmy day. The evenings are sparklingly clear.

San Francisco is a sophisticated city, and San Francisco women favor lightweight

wool suits and dresses. San Francisco men prefer the more conservative, light to medium weight suits.

CONTRIBUTED PAPERS

This meeting marks an innovation in the presentation of papers. About half of the contributed papers will be presented in Seminar style. In the very large California-Mural room, each author of a contributed paper will be provided with a table, chairs, a blackboard, and a sign announcing his paper. For a full session, normally three hours, he may discuss his paper with all comers or schedule repeated presentations, as he wishes.

Tables will be so spaced and divided that simultaneous conversations are practicable. (Please speak softly.) Authors may bring or send ahead to the hotel copies of their papers, presentation charts, or other visual aids that do not require electric power.

Contributed papers presented in traditional Sequential style sessions will be allotted 10 minutes for presentation and 5 minutes for discussion. Blackboards, 8½″ × 11″ viewgraph projectors and 35 mm slide projectors will be available for Sequential presentations.

COPIES OF PAPERS

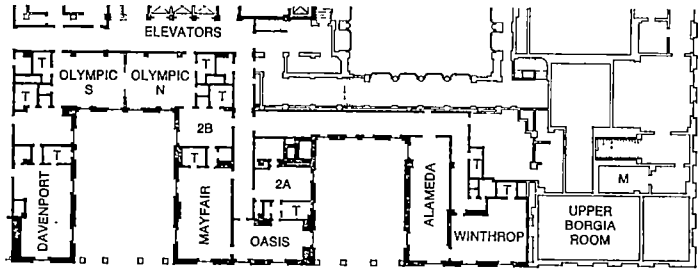
Requests for copies of papers and for information about presentations must be sent directly to the authors, not to the committee for the meeting, the session chairmen, or the Editor of *The Bulletin*.

IDENTIFICATION OF SESSIONS AND PAPERS

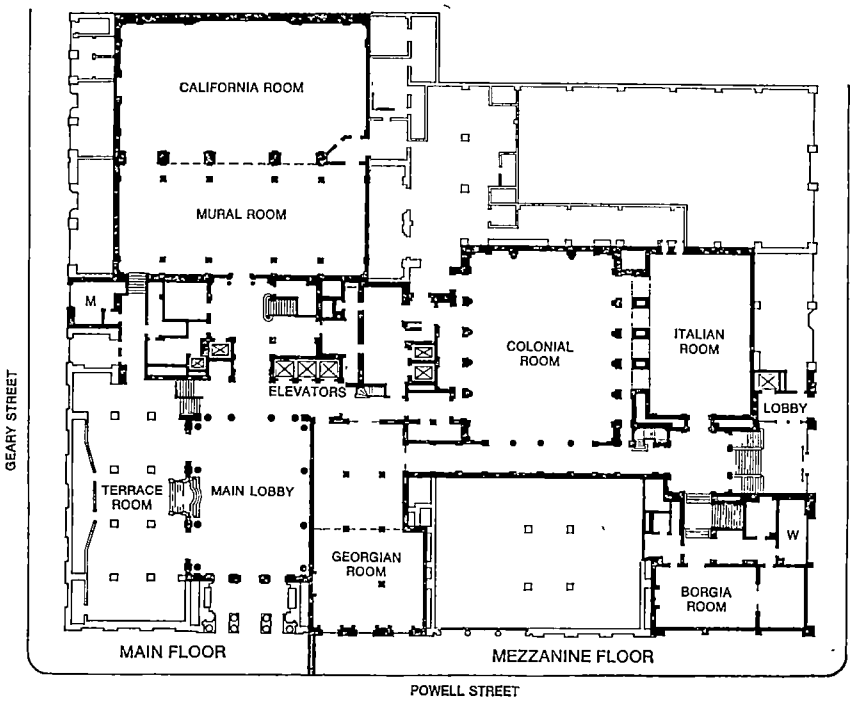
Abbreviations are used to identify the technical sessions and papers in these sessions. The first letter denotes day of the week—**W**, **T**. or **F**. The second denotes AM, PM, or evening, and is **A**, **P**, or **E**. A number occurs next, and identifies which of the simultaneous sessions is being considered. The last number identifies the location of a paper within the session. Invited papers are indicated by an asterisk.

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SECOND FLOOR



ST. FRANCIS HOTEL

SUMMARY OF EVENTS

Wednesday, May 1

		AM	
WA1*	Panel: How Should Managers Use Quantitative Thinking?	9:00–noon	Colonial Room
WA2*	Operations Research and the Administration of Justice	9:00–noon	Italian Room
WA3*	Computer Time-Sharing in Simulation and Gaming	9:00–11:30	Georgian Room
——	College on Simulation and Gaming: Business Meeting	11:30–noon	Georgian Room
WA4	Urban Issues and Managerial Decision Making	9:00–noon	Mayfair Room
WA5	Programming Applications	9:00–noon	Alameda Room
WA6	Military and Aerospace Applications	9:00–noon	Davenport Room

Wednesday, May 1

		PM	
WP1	Contributed Papers Seminar I	2:00–5:00	California-Mural Room
WP2*	Panel: Trends in the Theory of Vehicular Traffic Flow and Control	2:00–5:00	Colonial Room
——	Transportation Science Section: Business Meeting	5:00–5:30	Colonial Room
WP3*	Panel: New Concepts in Organizational Design	2:00–5:00	Italian Room
WP4*	Mathematical Programming	2:00–5:00	Georgian Room
WP5	Location, Networks, and Simulation	2:00–5:00	Alameda Room
WP6	Transportation and Airline Operations	2:00–5:00	Davenport Room
WE1*	Operations Research in University Problems	8:00–10:30	Colonial Room
WE2*	Workshop: Marketing Information Systems	8:00–10:30	Georgian Room

THURSDAY, May 2

		AM	
TA1	Contributed Papers Seminar II	9:00–noon	California-Mural Room
TA2*	Tactical Air Operations Models	9:00–noon	Colonial Room
TA3*	O. R. Developments in Investment and Banking	9:00–noon	Italian Room
TA4*	Inventory and Reliability Theory	9:00–noon	Georgian Room

TA5	Optimization	9:00–noon	ALAMEDA ROOM
TA6	National Resources	9:00–noon	DAVENPORT ROOM
——	ORSA Annual Business Meeting	noon–12:15	ITALIAN ROOM

Thursday Luncheon, May 2

TL*	John E. Walsh, Speaker	12:30–1:45	COLONIAL ROOM

Thursday, May 2

		PM	
TP1	Contributed Papers Seminar III	2:00–5:00	CALIFORNIA-MURAL ROOM
TP2*	Panel: Systems Analysis in State and Local Governments	2:00–5:00	COLONIAL ROOM
	Cost Effectiveness Section: Business Meeting	5:00–5:30	COLONIAL ROOM
TP3*	Operations Research Applications in Space	2:00–5:00	ITALIAN ROOM
——	Space Sciences Section: Business Meeting	5:00–5–30	ITALIAN ROOM
TP4*	Panel: Education in Military Operations Research	2:00–5:00	GEORGIAN ROOM
——	Military Applications Section: Business Meeting	5:00–5:30	GEORGIAN ROOM
TP5*	Research on Research	2:00–5:00	ALAMEDA ROOM
TP6	Optimization Theory	2:00–5:00	DAVENPORT ROOM
TE1*	George Elbert Kimball Memorial Session	7:00–8:00	GEORGIAN ROOM
TE2*	The Use of Computers in Teaching O.R.	8:00–10:30	ITALIAN ROOM
TE3*	Workshop: Research Methodology for Management Psychology	8:00–10:30	GEORGIAN ROOM

Friday, May 3

		AM	
FA1	Contributed Papers Seminar IV	8:30–11:00	CALIFORNIA-MURAL ROOM
FA2*	Panel: The Role of Planners and Planning in the Management Process and Structure	9:00–noon	COLONIAL ROOM
FA3*	Transportation System Applications	9:00–noon	ITALIAN ROOM
FA4*	Methodology for Measurement of Effectiveness	9:00–noon	GEORGIAN ROOM
FA5	Queuing and Inventory	9:00–noon	ALAMEDA ROOM
FA6	Investment, Banking and Marketing	9:00–noon	DAVENPORT ROOM

Friday Luncheon, May 3

FL*	John F. Briggs, Speaker	12:15–1:45	EMPRESS OF CHINA BALLROOM, GRANT AVENUE, CHINATOWN

Friday Afternoon, May 3

		PM	
FP1*	Panel: Management Sciences and Health Planning	2:00–5:00	COLONIAL ROOM
FP2*	Network Theory	2:00–5:00	ITALIAN ROOM
FP3	Cost-Effectiveness	2:00–5:00	DAVENPORT ROOM
FP4	Reliability, Statistics and Forecasting	2:00–5:00	ALAMEDA ROOM
FP5	Production Scheduling	2:00–5:00	GEORGIAN ROOM

INDEX OF PARTICIPANTS

ALAOGLU, L.: **WA6**
AMIR, R.: **WP1.1**
AMSTER, S. J.: **FA5.7**
ANDERSON, F. M.: **TP2.1**
ANDERSON, CAPT. G. L.: **WP1.12**
ANDERSON, JACQUELINE: **TA1.2**
ANDREW, G. M.: **TP1.2**
AVRIEL, M.: **TP6.4**
BACHMANN, J. A.: **TP1.9**
BAHARY, E. S.: **FP5.4**
BAISUCK, A.: **TA6.3**
BAKER, N. R.: **TP5.2**
BAKHRU, A. N.: **FP5.4**
BALINTFY, J. L.: **WA5.5, WA5.6, TE2.2**
BANDYOPADHYAY, R.: **TP1.27**
BARASH, M. M.: **TA1.13**
BARFOOT, C. B.: **WA6.2**
BARNES, R. W.: **TA1.9**
BARTON, R. F., **WP1.30**
BAXTER, R. F.: **FA2**
BAYRAKTAR, B.: **FP4.5**
BEAMER, J. H.: **TP6.6**
BECKMANN, M. J.: **WP6.1, WP6.3**
BELL, CAPT. L. F.: **TP4.1**
BELLIS, W. R.: **WP1.11**
BELLMORE, M.: **WA6.4, TA5.6**
BENNINGTON, G.: **WA6.4**
BENZ, G.: **FP4.10**
BERRA, P. B.: **TA1.13**
BETZ, F.: **WP1.28**
BHATTACHARYYA, R. K.: **FP5.4**
BISBEE, E. F.: **FA3**
BLACKBURN, II, C. R.: **WA5.5**
BLATTNER, W.: **FP2.2**
BLUMBERG, D. F. **FP5.10**
BLUMBERG, M. S. **FP1**
BLUMENTHAL, S.: **FA5.3**
BLUMSTEIN, A.: **WA2.4**
BODENHAMER, ROSA M.: **WA4.9**
BODIN, L. D.: **FP4.9**
BODO, J.: **FA1.17**
BOLING, R. W.: **FP5.1**
BONDER, S.: **TP4.1**
BOODMAN, D. M.: **WA4.3**
BORCH, K.: **TP1.18**
BORSTING, J. R. **TP4**
BOWEN, G. W.: **FA1.1**
BOWER, R. S.: **TP1.31**
BOYANOVITCH, D.: **FP4.3**
BRADLEY, G. H.: **TP6.1**
BRANCH, G. A. **TP1.29**
BRATTEN, F. W.: **TP1.15**
BRIGGS, J. F.: **FL**
BROCK, P.: **WP1.31**
BROSH, I.: **FP5.9**
BROWN, A. A.: **TE1**
BROWN, G. W. **WP4.1**
BROWN, R. G.: **TA1.4**
BRUNSCHWIG M. G.: **WA6.7**
BRYK, O.: **WP1.25**
BUCHIN, S. I.: **WA3**
BUGENHAGEN, T. G.: **FA4.6**
BULLARD, S.: **WA6.7**
BURTON, E. S.: **FP3.5**
CABOT, A. V.: **TA5.3**
CAIN, G. G.: **FA4.2**
CAMPBELL, H. S.: **WP6**
CARLETON, W. T.: **WP1.15**
CASEY, I. J.: **WP6.6**
CESARIO, F. J.: **TP1.16**
CHANDRASEKARAN, R.: **WE1.4**
CHARNES, A.: **TA3.3, TA6.11**
CHATTERJEE, S.: **TP1.8**
CHEN, G. K. C.: **FA1.8**
CHURCHMAN, C. W.: **WA1.1**
CLAVIER, P. A.: **WP1.14**
CLIFTON, RUTH E.: **TA1.19**
COHEN, W. M.: **FA1.12**
COOK, LT. J. M.: **FA1.7**
COOPER, E. H.: **WP1.6**
COX, D. F.: **WE2**

COYLE, R. G.: **WA4.2**
CROACH, J. W.: **FP5.3**
CROWSTON, W. B.: **WP5.8**
CURTIS, K.: **FA1.19**
CUSHEN, W. E.: **TP2.1**
DAKE, J. L.: **WP5.2**
DALRYMPLE, H.: **TA2.4**
DANIEL, J. N. JR.: **WA3.3**
DANTZIG, G. B.: **FP2.2**
DAVIS, J. B.: **TP1.15**
DAVIS, R. K.: **WA4.10**
DAWKINS, G. S.: **TP6.3**
DEAN, B. V : **WA4, TP5.1**
DENARDO, E. V.: **TP6.11**
DENNIS, L. C.: **WA5.6**
DICESARE, F.: **FA3.1**
DICKEY, J. W.: **FA1.30**
DIMITRIADIS, A. C.: **TP1.4**
DIMLING, J. A. JR.: **TA6.7**
DONAGHEY, C. E.: **WP1.5**
DREYFUS, S. E.: **FP2.1**
DRUDING, F. **WA1.1**
DUCKSTEIN, L.: **TP1.25**
DUNN, B. J.: **TP1.11**
EATON, K. R. JR.: **WP5.10**
EKLOF, W. D.: **FP2.6**
ELDREDGE, D. L.: **WP5.3**
ELICANO, R. V.: **WA4.8**
ELLETT, N. T.: **WA4.10**
ELTON, E. J.: **FA6.6**
EMERY, J.: **WP3.1**
EMLET, H. E. JR.: **FA1.27**
EMRICH, R. L.: **WA2.1**
ENGEL, J. H.: **TP3.1**
ETTER, D. O. JR.: **WA6.1**
EVAN, W. M.: **WP3.1**
EVANS, R. V.: **TE2.4, FA5.9**
EVERS, W. H.: **TA1.23**
FALKNER, C. H. **FA5.10**
FEDDERSEN, A. P.: **FA1.5**
FEND, A. V.: **TA2.3**
FENSKE, R. W.: **FP3.10**
FERNANDO, E. P. C.: **TP1.23**
FINKLER, G. A.: **TA1.11**
FISHBURN, P. C.: **WA4.5**
FLAGLE, C. D.: **TA6**
FLEISCHMAN, E. F.: **WA5.3**
FLORY, R. M.: **TA1.16**
FORD, L.R. JR.: **FP2.3**
FORGIE, D. J.: **FA1.10**
FRANKEL, E. G.: **FA3.4**
FREDERICK, D. G.: **TP1.22**
FREEMAN, R. J.: **TP3, TP3.3**
FREUDMAN, E.: **WP5.9**
FRITZ, C. H.: **TP1.30**
FULKERSON, D. R.: **FP2**
FURST, J. K.: **WP1.13**
GAFARIAN, A. V.: **WP2.1**
GALVIN, R. L.: **WA2.1**
GARGIULO, G. R.: **TP1.7**
GASS, S. I.: **WA2.2**
GAVER, D. P. JR.: **TA4.2, FA5**
GAZIS, D. C.: **WP2**
GEISLER, M. A.: **FP3**
GEOFFRION, A. M.: **WP4**
GHARE, P. M.: **TA5.2, FP2.7**
GILDEA, H.: **FA1.15**
GILFORD, DOROTHY: **WA1.1**
GINN, J. R.: **FA3.3**
GLASGALL, P. T.: **WP6.10**
GLASSEY, C. R.: **TA4.3**
GLAZER, H.: **TA6.5**
GLOVER, F. **WP4.3**
GLUSS, B.: **WP1.31**
GODFREY, M. B.: **FA3.2**
GOLDMAN, A. J.: **WP2.1**
GOLDSTEIN, L. J.: **FA5.4**
GOOBY, R.: **WE1.3**
GOODFRIEND, G. M.: **TA1.14**
GORRY, G. A.: **TP1.1**
GOTTSCHALK, H.: **TA5.1**
GOULD, F. J.: **WP4.2**
GRACE, H. A.: **FA1.31**
GRAVES, G. W.: **WP4.4**
GRAY, P.: **TA5.4**
GREENBERG, H. J.: **TA5.6**
GREENBERG, I.: **WP1.23**
GREENE, R. M. JR.: **WP1.29**
GREENE, J. H.: **WP5.4**
GREENE, T. E.: **TA2.2**
GREENWOOD, J. A.: **FA5.3**
GREENWOOD, F.: **WP1.27**

Gross, D.: **WA5.8**
Gross, N.: **FA2.1**
Grosse, R. N **FP1.1**
Grossman, D. A.: **TP2.1**
Grossman, H.: **TA3**
Gruber, M. J.: **FA6.6**
Gue, R. L.: **FP3.11**
Guha, D. K.: **WP1.4**
Gupta, S. K.: **TA1.15**
Gurel, M.: **WP6.8**
Gutstadt, L. R.: **WA6.11**
Haberstroh. C. J.: **WP3.1**
Hahn, Susan G.: **WA5.11**
Hahn, W. A : **TP5**
Haley, C W.: **FA6.1**
Hamson. R. L.: **FA6.4, FP3.4**
Hardgrave, W. W.: **WP4.5, TE2.4**
Harris, L.: **TA1.6**
Harris, R. D.: **TA1.31, FP3.3**
Hatry, H. P. **TP2**
Heap, B. J.: **WP6.9**
Herback, L.: **FA5.3**
Herrmann, W.: **WA2.2**
Heskiaoff, H.: **FA1.4**
Heyman, D P.: **FA5.1**
Heymann, M.: **TA1.28**
Hillier, F. S.: **FP5.1**
Hilsen, N. B.: **WA6.7**
Hinomoto, H.: **TA5.9**
Hitch, C. J.: **WA1**
Hoag, J. W.: **FA3.1**
Hoel, L. A.: **FA3.1**
Hoffman, R. B.: **WA2**
Hoffmann, T. R.: **TP1.2**
Hoggatt, A.: **TE2.4**
Hoover, T. E.: **TA6.1**
House, R. J. **WP3.1**
House, W. C.: **WP1.16**
Hoverland, H. A.: **WA1.1, TE3**
Howard, G. T.: **WA5.9**
Howland, D.: **FA1.20**
Huntoon, R. D.: **TP5.3**
Hurst, G. E. Jr.: **TA5.8**
Hurter, A. P. Jr.: **TA5.3**
Ignall, E.: **FP2.5**
Issacs, H.: **WA2.4**
Jackson, C. G.: **WA4.7**
Jackson, J. M.: **WP1.19**
Jago, W. H.: **FP2.3**
Jarvis, J. J.: **TA5.6**
Jenks, R.: **TA3.5**
Jha, C. K.: **FA1.9**
Jones, C. R.: **FP3.1**
Judy, R. W.: **FA1.25**
Kabak, I. W.: **FA6.3**
Katzenbach, E. L.: **WA1.1**
Keenan, J. M.: **WA1.1, TE3**
Kelly, E. M.: **TP1.10, WP1.22**
Kennedy, M.: **FA1.23**
Kidd, R. O.: **WP1.7**
Kim, C.: **WP1.8**
Kim, S. M.: **FA5.8**
King, B.: **FP4.2**
King, W. R.: **WP5.7**
Kingsley, J. D.: **WP6.7**
Kirby, M. J. L.: **TA6.11**
Kisiel, C. C.: **TP1.25**
Klahr, D.: **FA6.8**
Klasson, C. R.: **TA1.1**
Klein, M.: **FA1.3**
Knight, F. D.: **FP5.8**
Knight, K. E.: **WP3**
Koch, W H.: **WP6.5**
Koenigsberg, E.: **WA2.3 FL**
Korsak, A. J.: **TP1.29**
Koza, R. C.: **TA6.2, TA6.3, FA1.14**
Krabek, C. B.: **TP1.2**
Kranz, F. H.: **TP1.30**
Kruytbosch, C.: **WP1.28**
Langston, Joann: **WA6.6**
Larson, R.: **WA2.4**
Lasdon, L. S.: **FP5.6**
Lastavica, J.: **TP1.20**
Laughhunn, D. J.: **WP1.2, TP1.22**
Laurent, A. G.: **WA6.10**
Leavitt, H. J.: **WA1.1**
Lee, E. S.: **TA1.25**
Lesso, W. G.: **WP1.18**
Levine, J. B.: **FA1.25**
Liebman, M.: **TA5.10**
Little, J. D. C.: **WA4.1**
Littlechild, S. C.: **TA3.3, TA6.11**

LODATO, M. W.: **WA6.8**
LODISH, L. M.: **FA6.5**
LUBORE, S.: **WA6.4**
LUDEMAN, M. M.: **FP5.8**
LUTZ, R. P.: **TP1.5**
MACDONALD-TAYLOR, R.: **WP6.4**
MACKEY, J. E.: **FP5.6**
MACNAUGHTON-SMITH, P.: **WA2.3**
MACRAE, C. D.: **TA1.27**
MAGGIO, R. A.: **WP5.2**
MAHAR, T. A.: **FA4.7**
MANN, L. JR.: **WP1.10**
MARKS, E. S.: **TE2.1**
MARSHALL, A. W.: **TA4.1**
MARSHALL, R. D.: **TP3.2**
MARTIN, M. J. C.: **WA4.2**
MATHESON, J. D.: **TP1.12**
MATTHES, R. C.: **FP5.5**
MAUND, D. H.: **WP5.11**
MCCORD, J.: **WA6.3**
MCCREDIE, J. W. JR.: **FA1.11**
MCEWEN, J. T.: **WA2.2**
MCFARLAN F. W.: **WA3.2**
MCNICHOLS, G. R.: **FA6.8**
MCQUIE, R.: **WP1.21**
MEARS, W. J.: **TP6.3**
MEES, R.: **TA2.1**
MEIER, L. III.: **TP1.29**
MEIER, W. L. JR.: **TA6.9**
MELANDER, E. R.: **TP1.10**
MEREWITZ, L.: **FA4.3**
MEYER, C. F.: **WA5.10**
MIERCORT, F. A.: **TA1.30**
MILLER, B. L.: **TP6.11**
MILLER, D. S.: **TA6.9**
MILLER, G. H.: **TP2.1**
MILLER, J. R. III: **WP3.1, FA4.1**
MILLER, L. W.: **FP5**
MILLER, R. L.: **WP6.3, FA6.7**
MILLER, S. B.: **WA4.1**
MINTZ, S. E.: **FP3.9**
MITCHELL, J. E.: **TA1.9**
MODER, J. J.: **FA4.4**
MONTGOMERY, D. B.: **FA6.5**
MOORE, C. B.: **TP3.3**
MOORE, J. R.: **TP5.2**
MORAVEC, A. F.: **TA1.7**
MOREY, R. C.: **WA5.4**
MORGAN, H. E.: **TP5.3**
MORGENTHALER, G. W.: **TP3.3**
MOSS, J. H.: **FP1.1**
MUNJAL, P. K.: **WA5.1**
MYHRE, J. M.: **FP4.8**
NADDOR, E.: **TA6.6, TE2**
NAQI, M.: **TA1.12**
NATHAN, I.: **WP1.9**
NELSON, C. D.: **TA5.1**
NELSON, R. A.: **FA1.28**
NEMHAUSER, G L.: **WA5, WA5.9, FP2.6**
NEUHAUSER, J. J.: **TA6.3**
NEUVE-EGLISE, M.: **FA3.5**
NEWETT, R. J.: **WA5.10**
NICKL, J. J.: **FA4.4**
NISKANEN, W.: **TP4.1**
NUGENT, C. E.: **TE2.4, FA1.24**
OLIVER, R. M.: **WP2.1, WE1, WE3, FP2.4**
OLLE, T. W.: **TA1.8**
ORGLER, Y. E.: **FA6.2**
OVERLY, D. H.: **FA1.26**
OWEN, J.: **FA6.3**
PARDEE, F. S.: **FA4**
PEGELS, C. C.: **TA6.4**
PELLEGRINI, A. J.: **FA4.7**
PERIGARD, A. W.: **TP1.5**
PERILLA, O.: **TP1.17**
PERLMUTTER, H. V.: **WP3.1**
PERRY, G. H.: **FA1.13**
PERRY, M.: **TA1.5**
PESCHON, J. **TP1.29**
PETERKIN, S. R. **FP3.5**
PEYSER, T. K.: **FP4.6**
PFAFF, M.: **FP3.7**
PHILLIPS, M.: **TA3.4**
PHILLIPS, A. J.: **TA5.1**
PIERSKALLA, W. P.: **TP6, TP6.9**
PIFER, H. W. **FA1.20**
PLISKA, S. R.: **TA6.8**
POLLIN, COL. J. M.: **FA1.18**
POPPE, R. F.: **TP1.13**
PORTER, A.: **TA1.3**

PORTER, M. H.: **WP1.13**
PORTER, R. A.: **TA6.7**
PORTEUS, E. L.: **TP6.10**
POSNER, M. J.: **TA1.26**
PRABHU, N. U.: **TP1.3**
PRICE, S.: **FA1.6**
PRITSKER, A. A. B.: **WP5**
PROSCHAN, F.: **TA4.1**
PRYOR, M.: **FA2.1**
RAIKE, W. M.: **TP6.5**
RANDOLPH, P. H.: **TP1.11**
RAO, A. G.: **FP4.4**
RAO, M. R.: **FP2.2**
RAPPAPORT, A.: **TP1.21**
RAY, D. K.: **TA1.24**
REBELEIN, P. R.: **WA5.3**
REKLAITIS, G.: **TP6.7**
RESH, M.: **FP5.2**
RIECHERS, L.: **TA2.1**
ROBERTS, P. O.: **FA3.3**
ROCKAFELLAR, R. T.: **WP4.6**
ROSE, SHARON: **WP6.2**
ROSENSHINE, M.: **FA1.29**
ROSHOLT, G.: **TA2.4**
ROTHERY, R. W. **WP2.1**
ROTHKOPF, M. H.: **TA1.29**
RUBENSTEIN, A. H.: **TP5, TP5.4**
RUDE, J.: **WA3.4**
RUTENBERG, D.: **WP5.5**
SALTER, R. G.: **TA2**
SALTZMAN, S.: **TE2.4**
SANDEN, J. L.: **WA6.7**
SANDERS, J. L.: **FA1.18**
SANJOUR, W.: **FP3.5**
SAUNDERS, S. C.: **FP4, FP4.8**
SCARBOROUGH, C. W.: **WA3.3**
SCHAFFIR, W.: **FA2.1**
SCHARIER, R.: **FA2.1**
SCHANIEL, C. J.: **TP4.1**
SCHLAEFLI, J. L.: **TP1.14**
SCHMIDT, R. J.: **WP6.11**
SCHOFER, J. L.: **FA4.5**
SCHOTTA, C. JR.: **WA2.1**
SCHRADY, D. A.: **TA1.10**
SCHRUBEN, L. W.: **TA1.19**
SCHULTZ, R. D.: **WA6.9**
SCHUSSEL, G.: **FA1.6**
SCHWARTZ, L. E.: **TP1.6**
SCHWEITZER, P. J.: **WP1.3**
SEAGLE, J. P.: **FA1.22**
SEILER, K.: **WA6.5**
SELF, G. D.: **WP1.12**
SELMAN, J. H. N.: **TP1.24**
SELMAN, V.: **TA5.11**
SEVERSKY, M. D.: **FP5.7**
SHAKUN, M. F.: **FA6.10**
SHANNO, D. F.: **TA5.5**
SHAPIRO, A.: **FP4.4**
SHAPIRO, J. P.: **TP1.1**
SHARP, J. F.: **WP5.4**
SHENOY, B. V.: **WP5.1**
SHOUP, D. S.: **FA3.3**
SHUMAN, L.: **TA6.6**
SIFFERD, D. W.: **WP5.1**
SILVER, A. N.: **FP4.7**
SIMONS, G. R.: **FA1.14**
SIMPSON, JR., H. C.: **TP1.31**
SIMPSON, R. W.: **FA3.5**
SINGER, S.: **WP5.6**
SINGH, V. P.: **FA5.6**
SINGPURWALLA, N. D.: **FP4.11**
SINHA, B. K.: **TA1.15**
SISSON, R. L.: **TA1.15**
SKINNER, C. E.: **FA5.5**
SMITH, B. W.: **TA1.9**
SMITH, L. H.: **WA5.2**
SMITH, R. K.: **FP3.3**
SNYDER, J. C.: **WP5.4**
SOELBERG, P.: **WP3.1**
SOLAND, R. M.: **WA5.8**
SORRELL, R.: **FA1.15**
SOVEREIGN, M. G.: **TA1.22**
SPENCE, J. A.: **WA5.7**
SPRADLIN, B. C.: **WA4.4**
STANCILL, JR., J.: **TA3.2**
STANFEL, L. E.: **TA5.7**
STANKARD, M. JR.: **TA1.17**
STASCH, S. F.: **TA6.10**
STEELE, A. T.: **WA4.9**
STEMBER, J. A.: **FP3.6**
STERN, H. A.: **TP1.19**
STIMSON, D. H.: **WP1.28**

Stoller, D. S.: **WP1.24**
Strong, H. M.: **FP5.11**
Suslow, S.: **WE1.2**
Sussna, E.: **WA4.6**
Swersey, R. J.: **WP1.20**
Swinson, G. E.: **TP1.11**
Sykes, J. S.: **FA5.2**
Taylor, V. D.: **FP1.1**
Tetley, W. H.: **FA1.2**
Thamara, T.: **TA1.21**
Thatcher, R. M.: **TA4.3**
Tholen, A. D.: **WA3.1**
Thomas, W. H.: **FP5.11**
Throop, T. A.: **WA3.1**
Tollefson, J. O.: **FA1.21**
Tombach, H.: **TA1.18, TP4.1**
Topkis, D. M.: **TA4.4**
Topp, S. V.: **FP3.2**
Truenfels, P. M.: **WA5.3**
Turoff, M.: **FP3.8**
Van Gigch, J. P.: **TP1.28**
Van Horn, R. L.: **TL**
Van Tijn, D. E.: **TP1.26**
Vargha, L.: **WP6.8**
Veinott, A. F. Jr.: **TA4,TA4.6, FP2.5**
Vollmann, T. E.: **TE2.3, FA1.24**
Walker, Jr., W. F.: **FP4.1**
Walker, M. E.: **TP1.11**
Wallace, J. P.: **WP6.3, FA6.7**
Walsh, J. E.: **TL**
Walters, A. S.: **TA6.11**
Walters, L. E.: **TA5.2**
Wanger, M. L.: **WP6.2**
Ward, E. M.: **WP1.26**
Webber, D.: **TP6.8**
Weber, A. L.: **WP6.2**
Webster, Jr., F. E.: **FA6.5**
Weiler, H. E.: **FA2.1**
Weingartner, H. M.: **TA3.1, FA6**
Weinstein, J.: **FA1.4**
Weissman, A.: **FP1.1**
Wheeler, A. C.: **FA5.11**
Whisler, T.: **WP3.1**
White, L. S.: **TA1.20**
White, W. W.: **TP6.8**
Whitman, S. L.: **TP1.31**
Wilde, D. J.: **TP6.6, TP6.7, FA5.8**
Wilkins, L.: **WA2.4**
Williams, A. C.: **TP6.4**
Williams, R. D.: **TP1.11**
Winokur, Jr., H. S.: **FA5.4**
Woj, C. W.: **FA1.16**
Wolfman, B.: **WE1.1**
Wright, G. P. **TA4.5**
Wu, H. K.: **WP1.17**
Yates, Jr., J. T.: **TP5.3**
Young, J. P.: **TA6.6**
Zangwill, W. I.: **WP4.7, TA5**
Zimmerman, S. B.: **TP1.7**
Zionts, S.: **TP6.2**
Zoffer, H. J.: **WA4.6**

PROGRAM

of the

ORSA/TIMS JOINT MEETING

in

SAN FRANCISCO

WEDNESDAY AM, MAY 1 COLONIAL ROOM

Session WA1: 9:00 AM–noon

College on Management Psychology

Panel On: How Should Managers Use Quantitative Thinking?

Chairman: CHARLES J. HITCH

University of California, Berkeley, California

Panel Members.

C. WEST CHURCHMAN, *University of California, Berkeley, California.*
FRANK DRUDING, *Mellonics Division, Litton Industries, Sunnyvale, California*
DOROTHY GILFORD, *Mathematical Sciences Division, Office of Naval Research, Washington, D.C.*
EDWARD L. KATZENBACH, *Raytheon Education Company, Lexington, Massachusetts..*
HAROLD J. LEAVITT, *Stanford University, Stanford, California.*

Organizers.

J. M. KEENAN, *Western Michigan University, Kalamazoo, Michigan.*
H A. HOVERLAND, *Naval Postgraduate School, Monterey, California.*

WEDNESDAY AM, MAY 1 ITALIAN ROOM

Session WA2: 9:00 AM–noon

Operations Research and the Administration of Justice

Chairman: RICHARD B. HOFFMAN

University of California, Berkeley, California

WA2.1 ***The Role of Operations Research in Criminal Justice,** ROBERT L. EMRICH, *Department of Justice, Washington, D.C.*
Discussants. RAYMOND L. GALVIN, *Michigan State University, East Lansing, Michigan,* and CHARLES SCHOTTA, JR., *Virginia Polytechnic Institute, Blacksburg, Virginia*

WA2.2 ***A Mathematical Model for Prediction of Police Patrol Workload,** J. THOMAS MCEWEN, *Board of Police Commissioners, St. Louis, Missouri.*
Discussants. SAUL I. GASS, *Federal Systems Division, I.B.M., Rockville, Maryland,* and WILLIAM HERRMANN, *Systems Development Corporation, Santa Monica, California.*

WA2.3 ***Classification Theory, Crime and Operations Research,** PETER MACNAUGHTON-SMITH, *University of Toronto, Toronto, Canada.*
Discussant. ERNEST KOENIGSBERG, *Matson Research Corporation, San Francisco, California.*

WA2.4 ***A Feedback Model of a Total Criminal Justice System,** ALFRED BLUMSTEIN and RICHARD LARSON, *Institute for Defense Analyses, Arlington, Virginia.*
Discussants. LESLIE WILKINS, *University of California, Berkeley, California,* and HERBERT ISAACS, *Issacs-Dobbs System, Inc., Los Angeles, California.*

WEDNESDAY AM, MAY 1 GEORGIAN ROOM

Session WA3: 9:00–11:30 AM

College on Simulation and Gaming
Computer Time-Sharing in Simulation and Gaming

Chairman: STANLEY I. BUCHIN

Harvard Graduate School of Business Administration, Boston, Massachusetts

WA3.1 ***Time-Sharing Systems for War Gaming Applications,** ALBERT D. THOLEN and THOMAS A. THROOP, *Research Analysis Corporation, McLean, Virginia.*

WA3.2 ***Current and Future Uses of Computer Time-Sharing in Business Gaming,** F. WARREN MCFARLAN, *Harvard Graduate School of Business Administration, Boston, Massachusetts.*

WA3.3 ***Management Use of Simulation in Long-Range Planning for Colleges and Universities,** COLLIN W. SCARBOROUGH and JAMES N. DANIEL, JR., *Peat, Marwick, Livingston and Co., Boston, Massachusetts*

WA3.4 ***Why Time-Sharing?,** JAMES RUDE, *The Pillsbury Company, South Minneapolis, Minnesota.*

WEDNESDAY AM, MAY 1 GEORGIAN ROOM

11:30 AM–noon

College on Simulation and Gaming: Business Meeting

Chairman: THOMAS H. NAYLOR, *College Chairman*

WEDNESDAY AM, MAY 1 MAYFAIR RCOM

Session WA4: 9:00 A.M–noon

Urban Issues and Managerial Decision Making

Chairman: BURTON V. DEAN

Case Western Reserve Univ., Cleveland, Ohio

WA4.1 A Field Test of a Traffic Signal Setting Procedure, JOHN D. C. LITTLE, *Massachusetts Institute of Technology, Cambridge, Massachusetts,* and STEPHEN B. MILLER, *Aerospace Corporation, Los Angeles, California.*

WA4.2 The Economic Optimization of Refuse Collection, R. G. COYLE, *Harvard Business School, Cambridge, Massachusetts,* and M. J. C. MARTIN, *Bradford University, Bradford, England.*

WA4.3 Quantitative Decision-Making in Traffic Safety Management, DAVID M. BOODMAN, *Arthur D. Little, Inc., Cambridge, Massachusetts.*

WA4.4 Recognition of Community Hazard Problems: The Systems Dynamics, B. C. SPRADLIN, *Georgia Institute of Technology, Atlanta, Georgia.*

WA4.5 Information Analysis Without States of the World, PETER C FISHBURN, *Research Analysis Corporation, McLean, Virginia.*

WA4.6 An Experimental Study of Risk Taking: Individual vs. Shared Payoff Gambles, EDWARD SUSSNA and H. JEROME ZOFFER, *University of Pittsburgh, Pittsburgh, Pennsylvania.*

WA4.7 The Relation of the Inducement and Contribution Processes to the Energy and Entropy Functions, CHARLES G. JACKSON, *Bloomsburg State College, Bloomsburg, Pennsylvania.*

WA4.8 The Development of a State-Space Model of an Aerospace Enterprise and its Evaluation as a Practical Management Tool, RENE V. ELICANO, *Lear Siegler, Inc., Grand Rapids, Michigan.*

WA4.9 A Technique for Appraising Technical Progress, A. T. STEELE and ROSA M. BODENHAMER, *Sandia Corporation, Albuquerque, New Mexico*

WA4.10 Marketing and Equipment Utilization Planning, NORMAN T. ELLETT and RICHARD K. DAVIS, *Fry Consultants, Inc., Los Angeles, California.*

WEDNESDAY AM, MAY 1 ALAMEDA ROOM

Session WA5: 9:00 AM–noon

Programming Applications

Chairman: GEORGE L. NEMHAUSER

The Johns Hopkins University, Baltimore, Maryland

WA5.1 Use of Mathematical Programming in Sensitivity Analysis of Allocation of Various Crude Oils in Refineries, PREM K. MUNJAL, *System Development Corporation, Santa Monica, California.*

WA5.2 Iterative Quadratic Programming in Activation Analysis, LEE H. SMITH, *The University of Texas, Arlington, Texas.*

WA5.3 A Mathematical Programming Approach to the Scheduling of Experiments in Space, PAUL R. REBELEIN, PETER M. TREUENFELS, *Honeywell, Incorporated, Minneapolis, Minnesota,* and E. F. FLEISCHMAN, *National Aeronautics and Space Administration, Huntsville, Alabama.*

WA5.4 A Multi-Valued Evaluation of the Effectiveness of BMD Deployments by Mixed-Integer LP, RICHARD C. MOREY, *Stanford Research Institute, Menlo Park, California.*

WA5.5 The Application of An On-Line Integer Programming Code to Computer Assisted Menu Planning, C. RALPH BLACKBURN II and JOSEPH BALINTFY, *Tulane University, New Orleans, Louisiana.*

WA5.6 A Linear Programming Evaluation of Institutional Management Policies, LYMAN C. DENNIS and JOSEPH L. BALINTFY, *Tulane University, New Orleans, Louisiana.*

WA5.7 The Planning of Pipeline Networks, JOHN A. SPENCE, *W. D. Scott & Co. Pty. Ltd., North Sydney, Australia.*

WA5.8 A Branch and Bound Algorithm for a Strategic Deployment Model in which Aircraft Productivity Depends on Aircraft Mix, DONALD GROSS, *The George Washington University, Washington, D.C.,* and RICHARD M. SOLAND, *Research Analysis Corporation, McLean, Virginia.*

WA5.9 Optimal Capacity Expansion, G. T. HOWARD, *U. S. Naval Postgraduate School, Monterey, California,* and G. L. NEMHAUSER, *Johns Hopkins University, Baltimore, Maryland.*

WA5.10 Dynamic Programming for Feedlot Optimization, CARL F. MEYER, *Washington University, St. Louis, Missouri,* and ROBERT J. NEWETT, *Ralston Purina Company, St. Louis, Missouri.*

WA5.11 On the Optimal Cutting of Defective Glass Sheets, SUSAN G. HAHN, *IBM Corporation, New York, New York.*

WEDNESDAY AM, MAY—1 DAVENPORT ROOM

Session WA6: 9:00 AM–noon

Military and Aerospace Applications

Chairman: LEONIDAS ALAOGLU

Lockheed-California Co., Burbank, California

WA6.1 The Allocation of Defensive Fire, DANIEL O. ETTER, JR., *Institute for Defense Analyses, Arlington, Virginia.*

WA6.2 Stochastic Duels with Markov Dependent Kill Probabilities, C. BERNARD BARFOOT, *Center for Naval Analyses, Arlington, Virginia.*

WA6.3 An Input-Output Approach to the Selection of Industrial Target Sets, JOHN MCCORD, *The Boeing Company, Seattle, Washington.*

WA6.4 Extensions of the Tanker Scheduling Problem, M. BELLMORE, *The Johns Hopkins University, Baltimore, Maryland,* G. BENNINGTON and S. LUBORE, *The Mitre Corporation, Arlington, Virginia.*

WA6.5 A Satellite System Optimization Model, KARL SEILER, *Communications Satellite Corporation, Washington, D.C.*

WA6.6 Information System for War Games, JOANN LANGSTON, *Technical Operations, Incorporated, Alexandria, Virginia.*

WA6.7 SAMMIE—Scheduling Analysis Model for Mission Integrated Experiments, MICHAEL G. BRUNSCHWIG, SPENCER BULLARD and JOHN L. SANDEN, *Martin Marietta Corporation, Denver, Colorado;* NEIL B. HILSEN, *Bendix Corporation, Teterboro, New Jersey.*

WA6.8 Advanced Planning for Command and Control Systems, MICHAEL W. LODATO, *McDonnell Douglas Corporation, Huntington Beach, California.*

WA6.9 Decentralized Planning in the Naval Supply Systems Command, ROBERT D. SCHULTZ, *Naval Supply Systems Command, Washington, D.C.*

WA6.10 Bombing Problems, III, ANDRE G. LAURENT, *Wayne State University, Detroit, Michigan.*

WA6.11 A Countdown Decision Aid, L. R. GUTSTADT, *North American Rockwell, Downey, California.*

WEDNESDAY PM, MAY 1 CALIFORNIA-MURAL ROOM

Session WP1: 2:00–5:00 PM

Contributed Papers Seminar I

(All papers discussed simultaneously.)

WP1.1 Dynamic Programming under Piecewise Linearity Assumptions, REUVEN AMIR, *The Service Bureau Corporation, Palo Alto, California.*

WP1.2 Quadratic Binary Programming with Application to Capital Budgeting Problems, D. J. LAUGHHUNN, *University of Illinois, Urbana, Illinois.*

WP1.3 A Turnpike Theorem for Undiscounted Markovian Decision Processes, PAUL J. SCHWEITZER, *Institute for Defense Analyses, Arlington, Virginia.*

WP1.4 A New Approach of Solving Zero-One Linear Programming Problems, D. K. GUHA, *The Port of New York Authority, New York, New York.*

WP1.5 A Generalized Material Simulation System, CHARLES E. DONAGHEY, *University of Houston, Houston, Texas.*

WP1.6 Digital Simulation of Large Communications Networks, EDWARD H. COOPER, *Defense Communications Agency, Washington, D.C.*

WP1.7 A Dynamic Approach to Cost-Effectiveness, R. O. KIDD, *TRW Systems Group, Redondo Beach, California.*

WP1.8 A Parametric Programming Approach to Cost Benefit Analysis, CHAIHO KIM, *University of Santa Clara, Santa Clara, California.*

WP1.9 Management Decision Utilizing Cost-Effectiveness Modeling, IRWIN NATHAN, *Xerox Corporation, Webster, New York.*

WP1.10 Systems Analysis Approach to the Creation of Mathematical Models to Predict Highway Maintenance Costs, LAWRENCE MANN, JR., *Louisiana State University, Baton Rouge, Louisiana.*

WP1.11 Travel Time Through Successive Traffic Signals by a Mathematical Procedure, W. R. BELLIS, *New Jersey Department of Transportation, Trenton, New Jersey*

WP1.12 Maximizing Total Traffic Flow in a Parallel Street System With Freeway Access Constrained by Metering, CAPTAIN GERALD L. ANDERSON, *United States Air Force,* and GLEN D. SELF, *Texas A&M University, College Station, Texas.*

WP1.13 Computerized Corporate Planning Model, JOSEPH K. FURST and MARVIN H. PORTER, *Philadelphia Electric Company, Philadelphia, Pennsylvania.*

WP1.14 Confidence Level in Budgeting and Forecasting, P. A. CLAVIER, *Economatics, Pasadena, California.*

WP1.15 A Dynamic Programming Model for Corporate Financial Planning, WILLARD T.CARLETON, *Dartmouth College, Hanover, New Hampshire.*

WP1.16 The Usefulness of Sensitivity Analysis in Making Large, Long-Term Capital Investment Decisions, WILLIAM C. HOUSE, *Texas A&M University, College Station, Texas.*

WP1.17 Bank Examiner Criticisms, Bank Loan Defaults, and Economic Forecasting, HSIU-KWANG WU, *Boston University, Boston, Massachusetts.*

WP1.18 An Algorithm for the Optimal Selection, Sequence and Timing of Interrelated Major Capital Investments, WILLIAM G. LESSO, *University of Texas, Austin.*

WP1.19 Cost Factoring System for Force Readiness Projection (COFACTS), JOE M. JACKSON, *U.S. Army Office of Force Planning Analysis, Washington, D.C.*

WP1.20 Air Force Supply of Army Field Units: A Customer's Point of View, RICHARD J. SWERSEY, *University of Pennsylvania, Philadelphia, Pennsylvania.*

WP1.21 Experimental Design and Simulation of Cargo Ship Unloading, ROBERT MCQUIE, *Planning Research Corporation, Washington, D.C.*

WP1.22 The Merger Decision, EAMON M. KELLY, *The Pennsylvania State University, University Park, Pennsylvania.*

WP1.23 Prediction in a Poorly Structured Environment: Handicapping Pro Football, IRWIN GREENBERG, *New York University, New York, New York.*

WP1.24 Modelling Large-Scale Educational Systems, DAVID S. STOLLER, *U.S. Office of Education, Washington, D.C.*

WP1.25 Growth and Balanced Urbanization in America: Can Systems Analysis Help?, OLIVER BRYK, *Research Analysis Corporation, McLean, Virginia.*

WP1.26 A Computer System for Projecting Budget and Manpower Requirements of a Project-Oriented Organization, EARL M. WARD, *Westinghouse Electric Corporation, Pittsburgh, Pennsylvania.*

WP1.27 Managing and Motivating Computer Systems People, FRANK GREENWOOD, *Ohio University, Athens, Ohio*

WP1.28 Decision Criteria for the Funding of Higher Education, FRED BETZ, CARLOS KRUYTBOSCH and DAVID H. STIMSON, *University of California, Berkeley, California.*

WP1.29 Three Fundamental Laws of Systems, RICHARD M. GREENE, JR., *International Center for Executive Development, Glendora, California.*

WP1.30 Gaming the Large Public Accounting Firm, RICHARD F. BARTON, *Texas Technological College, Lubbock, Texas.*

WP1.31 Some New Statistics for Evaluating and Predicting the Support Performance of Complex Multi-Echelon Logistics Systems, PAUL BROCK and BRIAN GLUSS, *General Electric Company, Santa Barbara, California.*

P 9541

WEDNESDAY PM, MAY 1 COLONIAL ROOM

Session WP2: 2:00–5:00 PM

Transportation Science Section

Panel On: Trends in the Theory of Vehicular Traffic Flow and Control

Chairman: DENOS C. GAZIS

IBM Research Center, Yorktown Heights, New York

Panel Members:

ANTRANIG V. GAFARIAN, *System Development Corporation, Santa Monica, California.*
ALAN J. GOLDMAN, *National Bureau of Standards, Washington, D.C.*
ROBERT M. OLIVER, *University of California, Berkeley, California.*
RICHARD W. ROTHERY, *General Motors Research Laboratories, Warren, Michigan.*

WEDNESDAY PM, MAY 1 COLONIAL ROOM

5:00–5:30 PM

Transportation Science Section: Business Meeting

Chairman: RICHARD W. ROTHERY, *Section Chairman*

WEDNESDAY PM, MAY 1 ITALIAN ROOM

Session WP3: 2:00–5:00 PM

College on Organization

Panel On: New Concepts in Organizational Design

Chairman: KENNETH E. KNIGHT

Stanford University, Palo Alto, California

Panel Members:

JAMES EMERY, *University of Pennsylvania, Philadelphia, Pennsylvania.*
WILLIAM M. EVAN, *University of Pennsylvania, Philadelphia, Pennsylvania.*
CHADWICK J. HABERSTROH, *University of Wisconsin, Milwaukee, Wisconsin.*
ROBERT J. HOUSE, *McKinsey Foundation, New York, New York.*
JAMES MILLER, III, *Stanford University, Palo Alto, California.*
HOWARD V. PERLMUTTER, *Consultant, 50 Rue de Moillebeau, Geneva, Switzerland.*
PEER SOELBERG, *University of Wisconsin, Milwaukee, Wisconsin.*
THOMAS WHISLER, *University of Chicago, Chicago, Illinois.*

WEDNESDAY PM, MAY 1 GEORGIAN ROOM

Sessions WP4: 2:00–5:00 PM

Mathematical Programming

Chairman: ARTHUR M. GEOFFRION

University of California, Los Angeles, California

WP4.1 ***Recursive Approximation to Optimum Rules in Statistical Decision Processes,** GEORGE W. BROWN, *University of California, Irvine, California.*

WP4.2 ***Extensions of Lagrange Multipliers in Nonlinear Programming,** F. J. GOULD, *University of Chicago, Chicago, Illinois.*

WP4.3 ***Faces of an Integer Polyhedron for Groups of Prime Order,** FRED GLOVER, *University of Texas, Austin, Texas.*

WP4.4 ***A New Approach to Combinatorial Programming,** GLENN W. GRAVES, *University of California, Los Angeles, California.*

WP4.5 ***Location-Allocation Problems: A Survey,** WILLIAM W. HARDGRAVE, *Bell Telephone Laboratories, Inc., Holmdel, New Jersey.*

WP4.6 ***Conjugate Convex Functions and the Decomposition Principle,** R. T. ROCKAFELLAR, *University of Washington, Seattle, Washington.*

WP4.7 ***Cutting Plane Algorithms as Mappings on a Space of Sets,** W. I. ZANGWILL, *University of California, Berkeley, California.*

WEDNESDAY PM, MAY 1 ALAMEDA ROOM

Session WP5: 2:00–5:00 PM

Location, Networks, and Simulation

Chairman: A. ALAN B. PRITSKER

Arizona State Univ., Tempe, Arizona

WP5.1 **A Heuristic Simulation Approach for Locating Warehouses and Plant Facilities,** DANIEL W. SIFFERD and BHAMY V. SHENOY, *Continental Oil Company, Ponca City, Oklahoma.*

WP5.2 **Location and Production: An Algorithm,** R. A. MAGGIO and J. L. DAKE, *Georgia Institute of Technology, Atlanta, Georgia.*

WP5.3 **A Model for "Optimizing" Distribution Systems,** DAVID L. ELDREDGE, *Mead Johnson & Company, Evansville, Indiana.*

WP5.4 **An Algorithm for Solving the Multifacility Production-Transportation Problem with Nonlinear Production Costs,** J. FRANK SHARP, *New York University, New York, New York,* JAMES C. SNYDER and JAMES H. GREENE, *Purdue University, West Lafayette, Indiana.*

WP5.5 **Plant Location Under Economies of Scale in Production and Transportation,** DAVID RUTENBERG, *Carnegie-Mellon University, Pittsburgh, Pennsylvania.*

WP5.6 **Multi-centers and Multi-medians of a Graph with an Application to Optimal Warehouse Location,** SIDNEY SINGER, *Dunlap and Associates, Darien, Connecticut.*

WP5.7 **Historical Estimating Behavior and Network Simulations,** WILLIAM R. KING, *University of Pittsburgh, Pittsburgh, Pennsylvania.*

WP5.8 **DCPM: Network Reduction and Solution,** WALLACE B. CROWSTON, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

WP5.9 **Simulation of a Liquid Container Distribution System,** ERNEST FREUDMAN, *General American Transportation Corporation, Niles, Illinois.*

WP5.10 **Simulation in Power and Free Conveyor Systems,** KENNETH R. EATON, JR., *University of Michigan, Dearborn, Michigan.*

WP5.11 **Value of Time Share Terminal for Simulation Work, With Examples,** DONALD H. MAUND, *American Airlines, New York, New York.*

WEDNESDAY PM, MAY 1 DAVENPORT ROOM

Session WP6: 2:00–5:00 PM

Transportation and Airline Operations

Chairman: HARRISON S. CAMPBELL

The RAND Corporation, Santa Monica, California

WP6.1 **Predicting Traffic Loads in the Transportation Network of North Rhine-Westphalia,** MARTIN J. BECKMANN, *Brown University, Providence, Rhode Island.*

WP6.2 **Simulation of a Maritime Shipping System,** MURRAY L. WANG *U.S. Maritime Administration, Washington, D.C.,* SHARON ROSE ARNOLD L. WEBER, *National Bureau of Standards, Washington, D.C*

WP6.3 **Socio-Economic Evaluation of Urban Transportation Systems,** MARTIN J. BECKMANN, *Brown Univ., Providence, Rhode Island,* JAMES P. WALLACE, *General Motors Research Labs, Warren, Michigan,* and RALPH L. MILLER, *General Motors Corp., Detroit, Michigan.*

WP6.4 **Scheduling in a Transportation Network,** ROY MACDONALD-TAYLOR, *Bell Telephone Laboratories, Inc., Murray Hill, New Jersey.*

WP6.5 **Computer Aided Approach Spacing for Terminal Air Traffic Control,** W. H. KOCH, *National Aviation Facilities Experimental Center, Atlantic City, New Jersey.*

WP6.6 **Air Freight Transport and the Problem of Peak Demand,** IRVING J. CASEY, *Analytic Services Inc., Falls Church, Virginia.*

WP6.7 **Airline Operations and Planning Model,** JOE D. KINGSLEY, *Douglas Aircraft Company, Long Beach, California.*

WP6.8 **Airline Fleet Planning—Restricted Models,** MEHMET GUREL and LOUIS VARGHA, *The Boeing Company, Renton, Washington.*

WP6.9 **Time of Departure Assignment in Aircraft Scheduling,** BRADLEY J. HEAP, *Douglas Aircraft Company, Long Beach, California.*

WP6.10 **Probability: An Application to Projected Airline Cash Flow,** PAUL T. GLASGALL, *Douglas Aircraft Company, Long Beach, California.*

WP6.11 **Econometric Passenger Demand Forecasting Model,** RONALD J. SCHMIDT, *Douglas Aircraft Company, Long Beach, California.*

WEDNESDAY EVENING, MAY 1 COLONIAL ROOM

Session WE1: 8:00–10:30 PM

Operations Research in University Problems

Chairman: ROBERT M. OLIVER

University of California, Berkeley, California

WE1.1 ***Construction of Student Fees at the University of California,** BURTON WOLFMAN, *University of California, Berkeley, California.*

WE1.2 ***Student Enrollment Predictions,** SIDNEY SUSLOW, *University of California, Berkeley, California.*

WE1.3 ***A Model of Faculty Appointments and Promotions,** ROBERT M. OLIVER and ROBERT GOOBY, *University of California, Berkeley, California.*

WE1.4 ***On a Class of Quota Restricted Admission Policies,** RAMASWAY CHANDRASEKARAN, *Optimum Systems, Incorporated, Palo Alto, California.*

WEDNESDAY EVENING, MAY 1 GEORGIAN ROOM

Session WE2: 8:00–10:30 PM

College on Marketing

Workshop: Marketing Information Systems

Chairman: DONALD F. COX

Coca Cola Company, Atlanta, Georgia

THURSDAY AM, MAY 2 CALIFORNIA-MURAL ROOM

Session TA1: 9:00 AM–noon

Contributed Papers Seminar II

(All papers discussed simultaneously.)

TA1.1 Goal Setting Practices in American Industry: An Empirical Study to Assess State-of-the-Art, C. R. KLASSON, *University of Iowa, Iowa City, Iowa.*

TA1.2 The Optimal Planning Process: A Function of Information and Knowledge, JACQUELINE ANDERSON, *CONSAD Research Corporation, New York, New York.*

TA1.3 Syndrome: The Pathologically Work-Oriented Manager, ALBERT PORTER, *San Jose State College, San Jose, California.*

TA1.4 The Other Side of the Fence, ROBERT G. BROWN, *Curtiss-Wright Corporation, Woodridge, New Jersey.*

TA1.5 Measures of Association in Business Research, MICHAEL PERRY, *Oklahoma State University, Stillwater, Oklahoma.*

TA1.6 The Contributions of Decision Theory to Management Thinking, LAWRENCE HARRIS, *New York University, New York, New York.*

TA1.7 An Approach for Designing a Fundamental Information System, A. F. MORAVEC, *Booz-Allen Applied Research, Chicago, Illinois.*

TA1.8 Generalized Data Base Systems as an Aid to Quantitative Thinking, T. WILLIAM OLLE, *Radio Corporation of America, Cherry Hill, New Jersey.*

TA1.9 Effective Information Systems for Industrial Business Management, RICHARD W. BARNES, BEN W. SMITH and J. E. MITCHELL, *The Dow Chemical Company, Midland, Michigan.*

TA1.10 Inventory Record Accuracy, D. A. SCHRADY, *Naval Postgraduate School, Monterey, California.*

TA1.11 Computer Generation and Plotting of Discrete Probability Distributions, GENE A. FINKLER, *Equitable Life Assurance Society, New York, New York.*

TA1.12 The Cost and Schedule of a Computer Program, MUHAMMAD NAQI, *Computer Sciences Corporation, Richland, Washington.*

TA1.13 Computer Planning and Optimization of Automated Manufacturing Processes, P. BRUCE BERRA and MOSHE M. BARASH, *Purdue University, Lafayette, Indiana.*

TA1.14 Integrating Scientific and Behavioral Science Disciplines for Management Decision Making in a City Government Datacenter, GILBERT M. GOODFRIEND, *Daniel D. Howard Associates, Inc., Chicago, Illinois.*

TA1.15 Toward Aggregate Models of Educational Systems, BANI K. SINHA, SHIV K. GUPTA and ROGER L. SISSON, *University of Pennsylvania, Philadelphia, Pennsylvania.*

TA1.16 The Application of Logistic Principles to the Purchase, Storage and Distribution of Surplus Agricultural Commodities, ROBERT M. FLORY, *U.S. Department of Agriculture, Washington, D.C.*

TA1.17 On the Modeling of Relationships Between Performance and Resource Management in an Urban School District, MARTIN STANKARD, JR., *University of Pennsylvania, Philadelphia, Pennsylvania.*

TA1.18 A Case History of Education for Military Operations Research, HAROLD TOMBACH, *Northrop Corporation, Beverly Hills, California.*

TA1.19 A Test of Delivery Truck Route Design by Computer, LEONARD W. SCHRUBEN, *Stanford University, Stanford, California,* and RUTH E. CLIFTON, *Kansas State University, Manhattan, Kansas.*

TA1.20 Shortest Route Models for the Allocation of Inspection Effort on a Production Line, LEON S. WHITE, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

TA1.21 Exponential Smoothing with Automatic Weight Assignment, THOMAS THAMARA, *Harris Trust and Savings Bank, Chicago, Illinois.*

TA1.22 A Location-Allocation Model with Transport, Fixed and Volume-Related Costs, MICHAEL G. SOVEREIGN, *University of Illinois, Urbana, Illinois.*

TA1.23 Stochastic Programming, Optimal Control and the Repair Dispatch Problem, WILLIAM H. EVERS, *International Business Machines Corporation, Rockville, Maryland.*

TA1.24 Replacement Rules for Partially Observable Equipment, DEV K. RAY, *Bell Telephone Laboratories, Inc., Holmdel, New Jersey.*

TA1.25 Optimal Production Planning of Nonlinear, Multiproduct Systems, E. STANLEY LEE, *Kansas State University, Manhattan, Kansas.*

TA1.26 Closed Networks of Queues with Time Lags, MORTON J. POSNER, *University of Toronto, Toronto, Canada.*

TA1.27 A Dual Maximum Principle for Discrete-Time Linear Systems with Economic Interpretation, C. DUNCAN MACRAE, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

TA1.28 Optimal Search for a Maximum Using an Information Theoretic Approach, MICHAEL HEYMANN, *Mobil Research and Development Corporation, Princeton, New Jersey.*

TA1.29 A Model of Rational Competitive Bidding, MICHAEL H. ROTHKOPF, *Shell Development Company, Emeryville, California.*

TA1.30 Some Effects of Advertising on Optimal Inventory Policy, FREDERICK A MIERCORT, *Research Analysis Corporation, McLean, Virginia.*

TA1.31 A Cost Effectiveness Model, ROY D. HARRIS, *The University of Texas, Austin, Texas.*

THURSDAY AM, MAY 2 COLONIAL ROOM

Session TA2: 9:00 AM–noon

Military Applications Section
Tactical Air Operations Models

Chairman: RICHARD G. SALTER

Resource Management Corporation, Los Angeles, California

TA2.1 ***TIGER, An Air/Ground Tactical Combat Simulation,** LOREN RIECHERS and ROMAN MEES, *Planning Research Corporation, Los Angeles, California.*

TA2.2 ***Simulation Techniques for Analyzing Air Combat Systems,** TERRELL E. GREENE, *The RAND Corporation, Santa Monica, California.*

TA2.3 ***Comments on Aircraft Kill Probability Models,** A. V. FEND, *Stanford Research Institute, Menlo Park, California.*

TA2.4 ***Tactical Employment Analysis Model,** GENE ROSHOLT and HARRIS DALRYMPLE, *Planning Research Corporation, Los Angeles, California.*

(It is planned that three of the above papers will be presented briefly, with much of the session time devoted to informal discussion on the session topic.)

THURSDAY AM, MAY 2 ITALIAN ROOM

Session TA3: 9:00 AM–noon

O. R. Developments in Investment and Banking

Chairman: HARRY GROSSMAN

Security First National Bank, Los Angeles, California

TA3.1 ***Some New Views on the Common Criteria for Capital Budgeting Decisions,** H. MARTIN WEINGARTNER, *The University of Rochester, Rochester, New York.*

TA3.2 ***The Risk of Bankruptcy: The Third Discriminant in a Three-Discriminant Capital Budgeting Model,** JAMES MCN. STANCILL, JR., *University of Southern California, Los Angeles, California.*

TA3.3 ***Intertemporal Bank Asset Choice with Stochastic Dependence,** A. CHARNES, and S. C. LITTLECHILD, *Northwestern University, Evanston, Illinois.*

TA3.4 ***Using Scored Research Data in a Bank Marketing Problem,** MICHAEL PHILLIPS, *First National City Bank, New York, New York.*

TA3.5 ***The Synergistic Implications of O. R. Projects in Banking,** RANDOLPH JENKS, *Security First National Bank, Los Angeles, California.*

(After brief presentation of papers, the Chairman and authors will constitute a panel for a general critique, with audience participation.)

THURSDAY AM, MAY 2 GEORGIAN ROOM

Session TA4: 9:00 AM–noon

Inventory and Reliability Theory

Chairman: ARTHUR F. VEINOTT, JR.

Stanford University, Stanford, California

TA4.1 ***Inconsistency of the Maximum Likelihood Estimator in Certain Reliability Problems,** A. W. MARSHALL and F. PROSCHAN, *Boeing Scientific Research Laboratories, Seattle, Washington.*

TA4.2 ***Evaluation of System Readiness and Reliability Estimation Procedures,** D. P. GAVER, JR., *Carnegie-Mellon University, Pittsburgh, Pennsylvania.*

TA4.3 ***Optimal Control of a Service System,** C. R. GLASSEY, *University of California, Berkeley, California,* and R. M. THATCHER, *Boeing Scientific Research Laboratories, Seattle, Washington.*

TA4.4 ***Optimal Ordering and Rationing Policies in a Nonstationary Dynamic Inventory Model with n Demand Classes,** DONALD M. TOPKIS, *Yale University, New Haven, Connecticut.*

TA4.5 ***Optimal Policies for a Two Product Inventory System with Negotiable Lead Times,** GORDON P. WRIGHT, *Northwestern University, Evanston, Illinois.*

TA4.6 ***Minimum Concave Cost Solution of Leontief Substitution Models of Multi-Facility Inventory Systems,** ARTHUR F. VEINOTT, JR., *Stanford University, Stanford, California.*

THURSDAY AM, MAY 2 ALAMEDA ROOM

Session TA5: 9:00 AM–noon

Optimization

Chairman: WILLARD I. ZANGWILL

University of California, Berkeley, California

TA5.1 Large Networks of Buoys and the Traveling Repairman Problem, H. GOTTSCHALK, C. D. NELSON and A. J. PHILLIPS, *General Dynamics, San Diego, California.*

TA5.2 A Branch and Bound Algorithm for Multi-dimensional Knapsack Problem, P. M. GHARE and LAWRENCE E. WALTERS, *Virginia Polytechnic Institute, Blacksburg, Virginia.*

TA5.3 An Algorithm for Zero-One Programming and Its Application to Knapsack Problems, A. VICTOR CABOT, *Indiana University, Bloomington, Indiana,* and ARTHUR P. HURTER, JR., *Northwestern University, Evanston, Illinois.*

TA5.4 Exact Solution of the Fixed Charge Transportation Problem, PAUL GRAY, *Stanford Research Institute, Menlo Park, California.*

TA5.5 A Modified Secant Technique for Convex Function Optimization, DAVID F. SHANNO, *University of Chicago, Chicago, Illinois.*

TA5.6 Resolution of Gaps in Everett's Theorem, M. BELLMORE, J. J. JARVIS, *The Johns Hopkins University, Baltimore, Maryland,* and H. J. GREENBERG, *The Southern Methodist University, Dallas, Texas.*

TA5.7 Synchronization of Processes as Integer Programming Problems, LARRY E. STANFEL, *University of Florida, Gainesville, Florida.*

TA5.8 Adaptive Experimentation and Control: I. Known Change Precision, E. GERALD HURST, JR., *General Electric Company, Philadelphia, Pennsylvania.*

TA5.9 Coordination of Parallel Activities under Uncertain Demand or Activity Performance: Linear Programming Models of Markovian Decisions, HIROHIDE HINOMOTO, *University of Illinois, Urbana, Illinois.*

TA5.10 Development and Application of a Class of Three Person Zero and Non-Zero Sum Game Theory Models with Insufficient Information, MICHAEL LIEBMAN, *George Washington University, Falls Church, Virginia.*

TA5.11 A Methodology for the Use of Shadow Prices in the Parametric Analysis of Utility Payoffs in Game Theory, VICTOR SELMAN, *Communication and Systems, Inc., Falls Church, Virginia.*

THURSDAY AM, MAY 2 DAVENPORT ROOM

Session TA6: 9:00 AM–noon

National Resources

Chairman: CHARLES D. FLAGLE

Office of the Surgeon General, U. S. Public Health Service, Bethesda, Maryland

TA6.1 A Systems Approach to Long Range Facilities Planning in Higher Education, THOMAS E. HOOVER, *Ohio State University, Columbus, Ohio.*

TA6.2 The Use of Micro-Structural Input-Output Systems Analysis in Educational Resource Allocation Decision-Making, RUSSELL C. KOZA, *Rensselaer Polytechnic Institute, Troy, New York.*

TA6.3 A Projection Model for Higher Educational Systems Planning, RUSSELL C. KOZA, JOHN J. NEUHAUSER and ALLAN BAISUCK, *Rensselaer Research Corporation, Troy, New York.*

TA6.4 Establishing a Whole Blood Inventory Control System, C. CARL PEGELS, *State University of New York, Buffalo, New York.*

TA6.5 Management Science as a Vehicle for Training and Evaluation of Japanese Middle Management, HERBERT GLAZER, *The American University, Washington, D.C.*

TA6.6 A Model for Health Manpower Planning, E. NADDOR, L. SHUMAN and J. P. YOUNG, *John Hopkins University, Baltimore, Maryland.*

TA6.7 Prediction of Consumer Demand for New Recreation Items, JOHN A. DIMLING, JR. and ROBERT A. PORTER, *Spindletop Research, Inc., Lexington, Kentucky.*

TA6.8 A Mathematical Model of a Ground Water Basin, STANLEY R. PLISEA, *TRW Systems, Redondo Beach, California.*

TA6.9 Optimization of Water Quality Management, D. S. MILLER and W. L. MEIER, JR., *Texas A&M University, College Station, Texas.*

TA6.10 Disaggregative Measures in Validating Simulations of Social Science Phenomena, STANLEY F. STASCH, *Northwestern University, Chicago, Illinois.*

TA6.11 Horizon Models for Social Development, A. CHARNES, S. C. LITTLECHILD and A. S. WALTERS, *Northwestern University, Evanston, Illinois,* and M. J. L. KIRBY, *Dalhousie University, Halifax, Nova Scotia.*

THURSDAY NOON, MAY 2 ITALIAN ROOM

12:00 Noon–12:15 PM

Operations Research Society of America Annual Business Meeting

Chairman: JOHN E. WALSH, *President*
Operations Research Society of America

THURSDAY, MAY 1 COLONIAL ROOM

12:30–1:45 P.M.

Luncheon

Chairman: RICHARD L. VAN HORN
Carnegie-Mellon University, Pittsburgh, Pennsylvania

Speaker: JOHN E. WALSH

President, Operations Research Society of America 1967–1968
Southern Methodist University, Dallas, Texas

Subject: Retiring Presidential Address

THURSDAY PM, MAY 2 CALIFORNIA-MURAL ROOM

Session TP1: 2:00–5:00 PM

Contributed Papers Seminar III

(All papers discussed simultaneously.)

TP1.1 Integer Programming as a Sequential Decision Process, G. ANTHONY GORRY and JEREMY P. SHAPIRO, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

TP1.2 Exploitation of Solution Space Properties of Set Covering Problems, GARY M. ANDREW, T. R. HOFFMANN, *University of Minnesota, Minneapolis, Minnesota,* and C. B. KRABEK, *Control Data Corporation, Minneapolis, Minnesota.*

TP1.3 Non-equilibrium Theory of Storage and Queuing Models, N. U. PRABHU, *Cornell University, Ithaca, New York.*

TP1.4 Optimal Peak Inventory and Warehouse Capacity for a Seasonal Product, ANDRE C. DIMITRIADIS, *Trans World Airlines, Inc., New York, New York.*

TP1.5 Determining the Economic Feasibility of Reliability Analysis, A. WILLIAM PERIGARD, *Grumman Aircraft Engineering Corporation, Bethpage, New York,* and RAYMOND P. LUTZ, *New Mexico State University, University Park, New Mexico.*

TP1.6 An Inventory Model for Multi-Stage Production Processes, LAWRENCE ELLIOT SCHWARTZ, *Center for Naval Analyses of the University of Rochester, Arlington, Virginia.*

TP1.7 Analysis of Capacity Utilization—A Bulk Commodity Vessel, GRANVILLE R. GARGIULO and STEPHEN B. ZIMMERMAN, *Arthur Andersen & Co., New York, New York.*

TP1.8 A Programming Approach to the Optimum Design of Multivariate Surveys, SAMPRIT CHATTERJEE, *New York University, New York, New York.*

TP1.9 A Maintenance Shop Simulator, JOHN A. BACHMANN, *Virginia Polytechnic Institute, Blacksburg, Virginia.*

TP1.10 Internal Determinants of Capital Structure, EAMON M. KELLY and EUGENE R. MELANDER, *The Pennsylvania State University, University Park, Pennsylvania.*

TP1.11 A Model for Allocating Interceptors with Overlapping Batteries: A Method of Nonlinear Programming, B. J. DUNN, P. H. RANDOLEH, G. E. SWINSON, M. E. WALKER, *Braddock, Dunn and McDonald, Inc., El Paso, Texas* and R. D. WILLIAMS, *Sentinel System Evaluation Agency, White Sands Missile Range, New Mexico.*

TP1.12 A Generalized Weapon Allocation Game, JOHN D. MATHESON, *Analytic Services Inc., Falls Church, Virginia.*

TP1.13 The Role of the Scenario in Current Military System Procurement, RICHARD F. POPPE, *The Boeing Company, Seattle, Washington.*

TP1.14 Highway Congestion-Evaluating Urban Highway Improvement Alternatives, JOHN L. SCHLAEFLI, *Stanford Research Institute, Menlo Park, California.*

TP1.15 Operations Research Applications in Forest Fire Management Systems, FREDERICK W. BRATTEN and JAMES B. DAVIS, *Forest Fire Laboratory, Riverside, California.*

TP1.16 Operations Research in Outdoor Recreation, FRANK J. CESARIO, *Battelle Memorial Institute, Columbus, Ohio.*

TP1.17 Outline for Scientific Attack on Some Urban Problems, OSCAR PERILLA, *The Port of New York Authority, New York, New York.*

TP1.18 Decision Problems and the Control of Economic Processes, KARL BORCH, *The Norwegian School of Economics and Business Administration, Bergen, Norway.*

TP1.19 Integrating Computers into a Functioning Business Structure, HARRY A. STERN, *General Foods Corporation, White Plains, New York.*

TP1.20 Policy Decisions Can Be Automated, JOHN LASTAVICA, *The First National Bank of Boston, Boston, Massachusetts.*

TP1.21 Divisional Planning and Control Systems: A New Proposal, ALFRED RAPPAPORT, *Northwestern University, Evanston, Illinois.*

TP1.22 A Combination Bayesian—Programming Approach to New Product Selection, D. G. FREDERICK and D. J. LAUGHHUNN, *University of Illinois, Urbana, Illinois.*

TP1.23 Integrated Systems Planning for the Implementation of Planned Socio-Economic (Agricultural, Industrial, and Social) Development in Developing Countries, using Network Analysis, EUSTACE P. C. FERNANDO, *United Nations Development Programme, Colombo, Ceylon.*

TP1.24 The Manager Chooses Between/Among Alternatives: Game-Theoretic Approach, JEROME H. N. SELMAN, *Stevens Institute of Technology, Hoboken, New Jersey and U.S. Army Munitions Command, Dover, New Jersey.*

TP1.25 Water Resource Development and Management in the Tucson Basin, CHESTER C. KISIEL and LUCIEN DUCKSTEIN, *University of Arizona, Tucson, Arizona.*

TP1.26 A Model for Response to Multiple Profit Incentives, DAVID E. VAN TIJN, *Computer Applications Incorporated, Huntsville, Alabama.*

TP1.27 Investigation of the Decision Making System in a Large Single Enterprise—Some Theoretical Aspects, R. BANDYOPADHYAY, *University of Strathclyde, Glasgow, Scotland.*

TP1.28 The Impact of Technology on the Mental Content of Industrial Operations, JOHN P. VAN GIGCH, *Oregon State University, Corvallis, Oregon.*

TP1.29 Allocation of Research Funds, GLEASON A. BRANCH, JOHN PESCHON, ANDREW J. KORSAK and LEWIS MEIER III, *Stanford Research Institute, Menlo Park, California.*

TP1.30 Sequence Effectiveness Estimation, F. H. KRANZ and C. H. FRITZ, *North American Aviation, Inc., Downey, California.*

TP1.31 Time-Sharing Computers as a Means for Bringing Modern Management Practices to Small Banks and Small Communities, H. CLAY SIMPSON, JR., STEPHEN L. WHITMAN, and RICHARD S. BOWER, *Dartmouth College, Hanover, New Hampshire.*

THURSDAY PM, MAY 2 COLONIAL ROOM

Session TP2: 2:00–5:00 PM

Cost-Effectiveness Section

Panel On: Systems Analysis in State and Local Governments

Chairman: HARRY P. HATRY

George Washington University, Washington, D.C.

Panel Members:

F. MASON ANDERSON, *Budget Division, State of California, Sacramento, California.*

W. EDWARD CUSHEN, *National Bureau of Standards, Washington, D. C.*

DAVID A. GROSSMAN, *Bureau of the Budget, City of New York, New York, New York.*

GERALD H. MILLER, *Budget Bureau, State of Michigan, Lansing, Michigan.*

THURSDAY PM, MAY 2 COLONIAL ROOM

5:00–5:30 PM

Cost-Effectiveness Section: Business Meeting

Chairman: ALFRED BLUMSTEIN, *Section Chairman*

THURSDAY PM, MAY 2 ITALIAN ROOM

Session TP3: 2:00–5:00 PM

Space Sciences Section

Operation Research Applications in Space

Chairman: RAOUL J. FREEMAN

General Electric Company, Santa Barbara, California

TP3.1 ***Operations Research and Communication Satellites,** JOSEPH H. ENGEL, *Communications Satellite Corporation, Washington, D. C.*

TP3.2 ***Computer Assisted Resource Allocation for Satellite Systems,** R. D. MARSHALL, *System Development Corporation, Santa Monica, California.*

TP3.3 *Panel on:* **Operations Research Applications in Space.**

Panel Members:

GEORGE W. MORGENTHALER, *Martin Marietta Corporation, Denver, Colorado.*

CORDELL B. MOORE, *General Dynamics, Fort Worth, Texas.*

RAOUL J. FREEMAN, *General Electric Company, Santa Barbara, California.*

THURSDAY PM, MAY 2 ITALIAN ROOM

5:00–5:30 PM

Space Sciences Section: Business Meeting

Chairman: RAOUL J. FREEMAN, *Section Chairman*

THURSDAY PM, MAY 2 GEORGIAN ROOM

Session TP4: 2:00–5:00 PM

Military Applications Section

Panel On: Education in Military Operations Research

Chairman: JACK R. BORSTING

Naval Postgraduate School, Monterey, California

Panel Members:

CAPTAIN LLOYD F. BELL, *Naval ASW Center, Silver Spring, Maryland.*
SETH BONDER, *University of Michigan, Ann Arbor, Michigan.*
WILLIAM NISKANEN, *Institute for Defense Analyses, Arlington, Virginia.*
CARL J. SCHANIEL, *Naval Weapons Center, China Lake, California.*
HAROLD TOMBACH, *Northrop Corporation, Beverly Hills, California.*

THURSDAY, PM MAY 2 GEORGIAN ROOM

5:00–5:30 PM

Military Applications Section: Business Meeting

Chairman: CLINTON J. ANCKER, JR., *Section Chairman*

THURSDAY PM, MAY 2 ALAMEDA ROOM

Session TP5: 2:00–5:00 PM

College on Research and Development
Research on Research

Chairmen: WALTER A. HAHN

Environmental Science Services Administration, Rockville, Maryland

AND

ALBERT H. RUBENSTEIN

Northwestern University, Evanston, Illinois

TP5.1 ***A Research Program on the Management of Research and Development,** BURTON V. DEAN, *Case Western Reserve University, Cleveland, Ohio.*

TP5.2 ***Theoretical and Computational Analysis of R and D Project Utility Ranking Models,** J R. MOORE, *Krannert School of Industrial Administration,* and N. R. BAKER, *School of Industrial Engineering, Purdue University, Lafayette, Indiana.*

TP5.3 ***Exploratory NBS Studies of Benefit Cost Measurement in Research and Development,** J. T. YATES, JR., H. E. MORGAN and R. D. HUNTOON, *National Bureau of Standards, Gaithersburg, Maryland.*

TP5.4 ***Studies of the Interface between Research and Development and Related Activities,** A. H. RUBENSTEIN, *Northwestern University, Evanston, Illinois.*

Discussion. **The second half of this session will be devoted to audience and speaker discussion of the papers presented and additional items relating to ongoing and planned research on research activities.**

THURSDAY PM, MAY 2 DAVENPORT ROOM

Session TP6: 2:00–5:00 PM

Optimization Theory

Chairman: WILLIAM P. PIERSKALLA

Case Western Reserve Univ., Cleveland, Ohio

TP6.1 All Integer Integer Programming Algorithm, GORDON H. BRADLEY, *Stanford University, Stanford, California.*

TP6.2 Towards an Unifying Theory for Integer Linear Programming, STANLEY ZIONTS, *State University of New York, Buffalo, New York.*

TP6.3 Comparison of Integer Programming Algorithms, G. S. DAWKINS, *University of Houston, Houston, Texas,* and W. J. MEARS, *McDonnell Automation Company, Houston, Texas.*

TP6.4 Stochastic Programming With Separable Recourse Functions, M. AVRIEL and A. C. WILLIAMS, *Mobil Research and Development Corporation, Princeton, New Jersey.*

TP6.5 Application of Rejection Region Theory to the Solution and Analysis of Two-Stage Chance-Constrained Programming Problems, WILLIAM M. RAIKE, *University of Texas, Austin, Texas.*

TP6.6 Time Delay in Minimax Optimization of Unimodal Functions of One Variable, JOHN H. BEAMER and D. J. WILDE, *Stanford University, Stanford, California.*

TP6.7 Necessary Conditions for a Local Optimum without a priori Constraint Qualification, G. REKLAITIS and D. J. WILDE, *Stanford University, Stanford, California.*

TP6.8 A Partitioning Algorithm for Structured Linear Programming Problems, DAVID WEBBER, *IBM Corporation, White Plains, New York,* and WILLIAM W. WHITE, *IBM Corporation, New York, New York.*

TP6.9 Mathematical Programming with Increased Constraint Functions, WILLIAM P. PIERSKALLA, *Case Western Reserve University, Cleveland, Ohio.*

TP6.10 Successive Approximations and Infinite Horizon Discounted Sequential Decision Processes, EVAN L. PORTEUS, *4943 Manitoba Drive, Alexandria, Virginia.*

TP6.11 An Optimality Condition for Discrete Dynamic Programming with No Discounting, ERIC V. DENARDO and BRUCE L. MILLER, *The RAND Corporation, Santa Monica, California.*

THURSDAY EVENING, MAY 2 GEORGIAN ROOM

Session TE1: 7:00–8:00 PM

GEORGE ELBERT KIMBALL MEMORIAL SESSION

Chairman: ARTHUR A. BROWN

(Program to be announced)

THURSDAY EVENING, MAY 2 ITALIAN ROOM

Session TE2: 8:00–10:30 PM

The Use of Computers in Teaching O. R.

Chairman: ELIEZER NADDOR

The Johns Hopkins University, Baltimore, Maryland

TE2.1 ***Use of Simulation in Teaching Production and Inventory Control,** ELI S. MARKS, *University of Pennsylvania, Philadelphia, Pennsylvania.*

TE2.2 ***A Remote Terminal Application in Mathematical Programming Instruction,** JOSEPH L. BALINTFY, *Tulane University, New Orleans, Louisiana.*

TE2.3 ***A Gaming—Monte Carlo Simulation Approach to Teaching Some Fundamental Concepts of Operations Research,** THOMAS E. VOLLMANN, *Dartmouth College, Hanover, New Hampshire.*

TE2.4 **Panel on The Use of Computers in Teaching O.R.**

Panel Members:

RICHARD V. EVANS, *Case Western Reserve University, Cleveland, Ohio.*
WILLIAM W. HARDGRAVE, *Bell Telephone Laboratories, Holmdel, New Jersey.*
AUSTIN HOGGATT, *University of California, Berkeley, California.*
CHRISTOPHER E. NUGENT, *Dartmouth College, Hanover, New Hampshire.*
SIDNEY SALTZMAN, *Cornell University, Ithaca, New York.*

(Abstract TE2.4 contains an outline of the subject matter of this panel discussion and a listing of the equipment and the computer systems which will be available for demonstrations.)

THURSDAY EVENING, MAY 1 GEORGIAN ROOM

Session TE3: 8:00–10:30 PM

College on Management Psychology

Workshop: Research Methodology For Management Psychology

Chairmen: H. A. HOVERLAND

Naval Postgraduate School, Monterey, California

AND

J. M. KEENAN

Western Michigan University, Kalamazoo, Michigan

FRIDAY AM, MAY 3 CALIFORNIA-MURAL ROOM

Session FA1: 8:30–11:00 AM

Contributed Paper Seminar IV

(All papers discussed simultaneously)

FA1.1 Techniques in Vulnerability/Survivability Analysis, G. W. BOWEN, *Fort Worth Division, General Dynamics, Fort Worth, Texas.*

FA1.2 A System Analysis of Motor Transport Operations in the Saigon Area, W. H. TETLEY, *Philco-Ford Corporation, Fort Washington, Pennsylvania.*

FA1.3 Optimal Plant and Expansion, M. KLEIN, *The Dow Chemical Co., Midland, Michigan.*

FA1.4 A Graph-Theoretic Approach to Assembly Line Balancing Solution, H. HESKIAOFF and J. WEINSTEIN, *Western Electric Company, New York, New York.*

FA1.5 A Family of System Simulation Models, A. P. FEDDERSEN, *North American Rockwell Corporation, Anaheim, California.*

FA1.6 Applications-Oriented Operations Research: A Case History in Optimum Inventory Scheduling, GEORGE SCHUSSEL, *Brown Engineering, Huntsville, Alabama,* and STEVE PRICE, *Northrop Corporation, Hawthorne, California.*

FA1.7 Optimal Inventory Operating Policies under Relaxed Delivery Assumptions. LT. JOHN M. COOK, *Naval Postgraduate School, Monterey, California.*

FA1.8 A Bilateral Optimal Lot Model, GORDON K. C. CHEN, *University of Massachusetts, Amherst, Massachusetts.*

FA1.9 CPM Implementation in the Construction Industry—A Dream or a Challenge, CHANDRA K. JHA, *Tishman Construction Company, Chicago, Illinois.*

FA1.10 The Role of the Time-Sharing Medium in Management Decision, DONALD J. FORGIE, *The Ontario Paper Company, Ltd., Thorold, Ontario.*

FA1.11 Characteristics of a Processor-Shared Model of a Time-Shared Facility, JOHN W. MCCREDIE, JR., *Carnegie Mellon University, Pittsburgh, Pennsylvania.*

FA1.12 Measures of Effectiveness on a Real Time Basis, WALLACE M. COHEN, *Technical Operations Inc., Alexandria, Virginia.*

FA1.13 Computerization: Some Implications for Decision Making, G. H. PERRY, *System Development Corporation, Santa Monica, California.*

FA1.14 A Bayesian Approach to the Problem of Engineering Research and Test Expenditures Under Conditions of Uncertainty, GENE R. SIMONS and RUSSELL C. KOZA, *Rensselaer Polytechnic Institute, Troy, New York.*

FA1.15 The Determination of the Relative Value of Research Tasks Using the Law of Comparative Judgment, RAY SORRELL, *International Business Machines, Bethesda, Maryland,* and HARRY GILDEA, *Peat, Marwick, Livingston & Co., Washington, D. C.*

FA1.16 Model of the Management Process as a Framework for Analysis and Understanding, C. W. WOJ, *General Refractories Company, Philadelphia, Pennsylvania.*

FA1.17 Causative Analysis, JOSEPH BODO, *Sylvania Electronic Defense Laboratories, Mountain View, California.*

FA1.18 Theoretical Foundations for Teleological Systems, JERRY L. SANDERS and COL. JACK M. POLLIN, *The University of Arizona, Tucson, Arizona.*

FA1.19 The Modeling of Consumer Markets for an Adaptive Marketing Decision System, KERRY CURTIS, *University of Pennsylvania, Philadelphia, Pennsylvania.*

FA1.20 Utilization of a Patient-Care Model, DANIEL HOWLAND, *The Ohio State University, Columbus, Ohio.*

FA1.21 Planning the Allocation of Effort to Projects Under Uncertainty, JOHN O. TOLLEFSON, *The University of Kansas, Lawrence, Kansas.*

FA1.22 Risk Aversion in Contract Negotiation, JOHN P. SEAGLE, *State University of New York, Buffalo, New York.*

FA1.23 Depreciation—A Model for Estimating the Opportunity Cost of Different Styles and Rates of Facility Utilization, MILES KENNEDY, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

FA1.24 User Designed Computer Systems for Medical Research, CHRISTOPHER E. NUGENT and THOMAS E. VOLLMANN, *Dartmouth College, Hanover, New Hampshire.*

FA1.25 The Integration of Systems Analysis and Program Budgeting in University Planning and Administration, JACK B. LEVINE and RICHARD W. JUDY, *University of Toronto, Toronto, Ontario.*

FA1.26 The Use of Effectiveness Measures in Decision-Making by Local Government, DON H. OVERLY, *Wayne State University, Detroit, Michigan.*

FA1.27 Use of Cost-Benefit Analysis in Solutions to National Health Problems, HARRY E. EMLET, JR., *Analytic Services, Inc., Falls Church, Virginia.*

FA1.28 A Cost Effectiveness Study of County Road Building and Maintenance Systems, RONALD A. NELSON, *Box 643, Rockville, Maryland.*

FA1.29 Random Patrol Scheduling, MATTHEW ROSENSHINE, *Cornell Aeronautical Laboratory, Inc., Buffalo, New York.*

FA1.30 Models for Optimizing the Use of Housing in New Towns, JOHN W. DICKEY, *Virginia Polytechnic Institute, Blacksburg, Virginia.*

FA1.31 A Systems Approach to Employment after Orthopedic Rehabilitation, HARRY A. GRACE, *University of Southern California, Los Angeles, California.*

FRIDAY AM, MAY 3 COLONIAL ROOM

Session FA2: 9:00 AM–noon

College on Planning

Panel on: The Role of Planners and Planning in the Management Process and Structure

Chairman: RALPH F. BAXTER

Avery Products Corporation, San Marino, California

Panel Members:

NORMAN GROSS, *Warner-Lambert Pharmaceutical Company, Morris Plains, New Jersey.*

WALTER SCHAFFIR, *Western Union Telegraph Company, New York, New York.*

H. EMMANUEL WEILER, *Purdue University, Lafayette, Indiana.*

ROBERT SCHAIRER, *Lockheed Aircraft Corporation, Burbank, California.*

MILLARD PRYOR, *Singer Company, New York, New York.*

FRIDAY AM, MAY 3 ITALIAN ROOM

Session FA3: 9:00 AM–noon

Transportation Science Section
Transportation System Applications

Chairman: E. FARNSWORTH BISBEE

Massachusetts Institute of Technology, Cambridge, Massachusetts

FA3.1 ***On the Interface Between a Regional Transportation System and the Central Business District,** LESTER A. HOEL, FRANK DICESARE and JAMES W. HOAG, *Carnegie Mellon University, Pittsburgh, Pennsylvania.*

FA3.2 ***Merging Delays in Automated Ground Transportation Systems,** MICHAEL B. GODFREY, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

FA3.3 ***A Model for the Simulation of Transfer Operations in Multi-Mode Transportation Networks,** PAUL O. ROBERTS, DONALD S. SHOUP, and J. ROYCE GINN, *Harvard University, Cambridge, Massachusetts.*

FA3.4 ***Conditional Networks in Intermodal Transportation Transfer Problems,** ERNST G. FRANKEL, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

FA3.5 ***Determining Vehicle Size and Frequency of Service for a Short Haul Air Transport System,** ROBERT W. SIMPSON and MICHAEL NEUVE-EGLISE, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

FRIDAY AM, MAY 3 GEORGIAN ROOM

Session FA4: 9:00 AM–noon

Cost-Effectiveness Section

Methodology for Measurement of Effectiveness

Chairman: FREDERICK S. PARDEE

The RAND Corporation, Santa Monica, California

(Invited Papers are Prize Winners in 1967 Cost-Effectiveness Essay Contest)

FA4.1 ***First Prize: A Systematic Procedure for Assessing the Worth of Complex Alternatives,** JAMES R. MILLER III, *Stanford University, Palo Alto, California.*

FA4.2 ***Second Prize: Benefit-Cost Estimates for the Job Corps,** GLEN G. CAIN, *University of Wisconsin, Madison, Wisconsin.*

FA4.3 ***Second Prize: The Production Function in the Public Sector: Production of Postal Services in the U. S. Post Office,** LEONARD MEREWITZ, *University of California, Berkeley, California.*

FA4.4 ***Second Prize: An Optimal Allocation of Resources for the Capital Budgeting Problem,** JOSEPH J. MODER, *University of Miami, Coral Gables, Florida,* and JAMES J. NICKL, *Lockheed Aircraft Corporation, Burbank, California.*

FA4.5 **A Cost-Effectiveness Framework for Urban Transportation Plan Evaluation,** JOSEPH L. SCHOFER, *University of Illinois, Chicago, Illinois.*

FA4.6 **Using Estimates of the Enemy's Cost and Effectiveness to Weight Threats,** THOMAS G. BUGENHAGEN, *The Johns Hopkins University, Silver Spring, Maryland.*

FA4.7 **A Model to Assist Army Force Planners in the Evaluation of Multiple Measures of Effectiveness,** THOMAS A. MAHAR and ANTHONY J. PELLEGRINI, *Research Analysis Corporation, McLean, Virginia.*

FRIDAY AM, MAY 3 ALAMEDA ROOM

Session FA5: 9:00 AM—noon

Queuing and Inventory

Chairman: DONALD P. GAVER

Carnegie-Mellon Univ., Pittsburgh, Pennsylvania

FA5.1 Optimal Priority Assignments in Queueing, DANIEL P. HEYMAN, *Bell Telephone Laboratories, Inc., Holmdel, New Jersey.*

FA5.2 Analysis of a Data Communications System Using a Dual-Queue Single Server Queuing Model, JACK S. SYKES, *Bell Telephone Laboratories, Holmdel, New Jersey.*

FA5.3 Waiting Time Between Events for Superimposed Renewal Processes, S. BLUMENTHAL, J. A. GREENWOOD and L. HERBACK, *New York University, New York, New York.*

FA5.4 The Time-Dependent Solution to a Many Server Queue, With Some Implications for Decision-Making, HERBERT S. WINOKUR, JR., *Office of the Assistant Secretary of Defense, Washington, D. C.,* and LAWRENCE J. GOLDSTEIN, *Yale University, New Haven, Connecticut.*

FA5.5 A Numerical Inversion of the Pollaczek-Khintchine Formula, CHARLES E. SKINNER, *International Business Machines Corporation, Poughkeepsie, New York.*

FA5.6 Markovian Queues with Heterogeneous Servers, VIJENDRA PAL SINGH' *Case Western Reserve University, Cleveland, Ohio.*

FA5.7 Approximate Spares Optimization for Complex Systems, S. J. AMSTER, *Bell Telephone Laboratories, Whippany, New Jersey.*

FA5.8 A Sufficient Condition for Partial Control of Linear Inventory Systems, S. M. KIM and D. J. WILDE, *Stanford University, Stanford, California.*

FA5.9 Inventory Control of By-Products, RICHARD V. EVANS, *Case Western Reserve University, Cleveland, Ohio.*

FA5.10 Optimal Ordering Policies for a Continuous Time, Deterministic Inventory Model, CHARLES H. FALKNER, *University of Wisconsin, Madison, Wisconsin.*

FA5.11 Finite-Horizon Multiproduct Inventory Models with Set-Up Costs, ALAN C. WHEELER, *Washington University, St. Louis, Missouri.*

FRIDAY AM, MAY 3 DAVENPORT ROOM

Session FA6: 9:00 AM–noon

Investment, Banking and Marketing

Chairman: H. MARTIN WEINGARTNER

The University of Rochester, Rochester, New York

FA6.1 Capital Constraints in Bank Optimization Models, CHARLES W. HALEY, *University of Washington, Seattle, Washington.*

FA6.2 Cash Budgeting: An Analytical Model, YAIR E. ORGLER, *Federal Deposit Insurance Corporation, Washington, D. C.*

FA6.3 Random Variables, The Time Value of Money and Capital Expenditures, IRWIN W. KABAK and JOEL OWEN, *New York University, New York, New York.*

FA6.4 Cross Fertilization in a Return-on-Investment Business Model, ROBERT L. HAMSON, *General Electric Company, Philadelphia, Pennsylvania.*

FA6.5 A Dynamic Sales Call Policy Model, LEONARD M. LODISH and DAVID B. MONTGOMERY, *Massachusetts Institute of Technology, Cambridge, Massachusetts,* and FREDERICK E. WEBSTER, JR., *Dartmouth College, Hanover, New Hampshire.*

FA6.6 The Ex-Dividend Behavior of Stock Prices, EDWIN J. ELTON and MARTIN J. GRUBER, *New York University, New York, New York.*

FA6.7 Consumer Behavior Models for the Automotive Market, JAMES P. WALLACE, *General Motors Research Labs, Warren, Michigan,* and RALPH L. MILLER, *General Motors Corp., Detroit, Michigan.*

FA6.8 A Study of Consumer's Cognitive Structure for Cigarette Brands, DAVID KLAHR, *University of Chicago, Chicago, Illinois.*

FA6.9 A Model of Conflict Behavior in Extended Prisoner's Dilemma, GERALD R. MCNICHOLS, *U. S. Air Force, Washington, D. C.*

FA6.10 A Mathematical Model for Decision-Making in Multistage Marketing Channels, MELVIN F. SHAKUN, *New York University, New York, New York.*

FA6.11 A Comparison of Decision Strategies Within a Simulated Oligopolistic Market, HOWARD W. PIFER, *Harvard Graduate School of Business Administration, Falls Church, Virginia.*

FRIDAY, MAY 3 THE EMPRESS OF CHINA BALLROOM
GRANT AVENUE, CHINATOWN

12:15–1:45 P.M.

Luncheon

Chairman: ERNEST KOENIGSBERG

Matson Research Corporation, San Francisco, California

Speaker: JOHN F. BRIGGS

Executive Secretary, Committee of Information Systems, The Council of State Governments, Chicago, Illinois

Subject: Management Research in State and Local Governments

FRIDAY PM, MAY 3 COLONIAL ROOM

Session FP1: 2:00–5:00 PM

Health Applications Section

Panel On: Management Sciences and Health Planning

Chairman: MARK S. BLUMBERG, M.D.

University of California, Berkeley, California

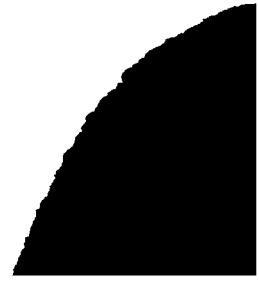
Panel Members:

ROBERT N. GROSSE, *Department of Health, Education, and Welfare, Washington, D. C.*

JOHN H. MOSS, *U. S. Public Health Service, Bethesda, Maryland.*

VINCENT D. TAYLOR, *The RAND Corporation, Santa Monica, California.*

ARTHUR WEISSMAN, *Kaiser Foundation Health Plan and Hospitals, Oakland, California.*



FRIDAY PM, MAY 3 ITALIAN ROOM

Session FP2: 2:00–5:00 PM

Network Theory

Chairman: D. R. FULKERSON

The RAND Corporation, Santa Monica, California

FP2.1 ***An Appraisal of Some Shortest Path Algorithms,** S. E. DREYFUS, *University of California, Berkeley, California.*

FP2.2 ***Finding A Cycle with Minimum Cost to Time Ratio in a Graph,** GEORGE B. DANTZIG, *Stanford University, Palo Alto, California,* WILLIAM BLATTNER, *U. S. Steel Corporation, Monroesville, Pennsylvania,* and M. R. RAO, *U. S. Steel Corporation, Monroesville, Pennsylvania.*

FP2.3 ***An Urban Transportation Simulation,** L. R. FORD, JR. and W. H. JAGO, *General Research Corporation, Santa Barbara, California.*

FP2.4 ***An Entropy Minimizing Traffic Distribution Model,** ROBERT M. OLIVER, *University of California, Berkeley, California.*

FP2.5 ***Substitution Properties of Network Flows,** EDWARD IGNALL, *Columbia University, New York, New York,* and ARTHUR F. VEINOTT, JR., *Stanford University, Palo Alto, California.*

FP2.6 **A Multiperiod Transportation Problem with Stochastic Demands,** W. D. EKLOF, *The Johns Hopkins University, Baltimore, Maryland* and G. L. NEMHAUSER, *The Johns Hopkins University, Baltimore, Maryland.*

FP2.7 **A Graphical Interpretation of the Multi-index Transportation Problem,** P. M. GHARE, *Virginia Polytechnic Institute, Blacksburg, Virginia.*

FRIDAY PM, MAY 3 DAVENPORT ROOM

Session FP3: 2:00–5:00 PM

Cost-Effectiveness

Chairman: MURRAY A. GEISLER

The RAND Corporation, Santa Monica, California

FP3.1 **On the Theory of Cost-Benefit Analysis,** CARL R. JONES, *Naval Postgraduate School, Monterey, California.*

FP3.2 **A Cost-Production Model of a USAEC Isotope Production Facility: Use in Cost Effectiveness Studies,** S. V. TOPP, *E. I. du Pont de Nemours & Co., Aiken, South Carolina.*

FP3.3 **A Cost-Effectiveness Approach to Facilities Layout,** ROY D. HARRIS and ROLAND K. SMITH, *The University of Texas, Austin, Texas.*

FP3.4 **R&D Decisions by Cost Effectiveness?,** ROBERT L. HAMSON, *General Electric Company, Philadelphia, Pennsylvania.*

FP3.5 **A Cost-Effectiveness Approach to Urban Air Pollution Abatement,** ELLISON S. BURTON, SAMUEL R. PETERKIN and WILLIAM SANJOUR, *Ernst & Ernst, Washington, D. C.*

FP3.6 **Methodology for Measures of Effectiveness,** JEROME A. STEMBER, *Hughes Aircraft Company, Culver City, California.*

FP3.7 **A Methodology for the Measurement of Complex Organizational Learning Processes,** MARTIN PFAFF, *Michigan State University, East Lansing, Michigan.*

FP3.8 **A Heuristic Compromise between Probability of Success and Limited Resources,** MURRAY TUROFF, *Institute for Defense Analysis, Arlington, Virginia.*

FP3.9 **Towards an Understanding of Network Cost Model Characteristics and Classifications,** STANTON E. MINTZ, *Litton Systems, Inc., Van Nuys, California.*

FP3.10 **Integrating Productivity Measurement with Resource Allocation through Linear Programming,** RUSSELL W. FENSKE, *University of Wisconsin, Milwaukee, Wisconsin.*

FP3.11 **Mathematical Programming in Institutional Menu Planning,** RONALD L. GUE, *Southern Methodist University, Dallas, Texas.*

FRIDAY PM, MAY 3 GEORGIAN RCOM

Session FP4: 2:00–5:00 PM

Reliability, Statistics and Forecasting

Chairman: S. C. SAUNDERS

Boeing Scientific Research Center, Seattle, Washington

FP4.1 Solution of Least Squares Problems by Linear Programming, WILLIAM F. WALKER, JR., *First National City Bank, New York, New York.*

FP4.2 Errors in the Variables with Inconstant Variances, BENJAMIN KING, *University of Chicago, Chicago, Illinois.*

FP4.3 An Application of the Sampling Theorem of Information Theory to the Reconstruction of Time Series, D. BOYANOVITCH, *Morgan Guaranty Trust Company of New York, New York New, York.*

FP4.4 Using Evolutionary Spectra for Forecasting Seasonal Time Series, AMBAR G. RAO and ARTHUR SHAPIRO, *Mobil Oil Corporation, New York, New York.*

FP4.5 Adaptive Forecasting with General Exponential Smoothing and a Related Experimental Design for Sensitivity Analysis, BULENT BAYRAKTAR, *Sinclair Oil Corporation, New York, New York.*

FP4.6 Graphical Display Algorithms for Multivariate Prediction and Optimization Studies: An Application to the Field of Metals, T. K. PEYSER, *IIT Research Institute, Chicago, Illinois.*

FP4.7 The Application of Multivariate Statistics to Terrain Mapping Problems, A. N. SILVER, *Martin Marietta Corporation, Denver, Colorado.*

FP4.8 Approximate Confidence Limits for Complex Systems with Exponential Time Until Failure of the Components, J. M. MYHEE, *Claremont Mens College, Claremont, California* and S. C. SAUNDERS, *Boeing Scientific Research Laboratories, Seattle, Washington.*

FP4.9 Approximations to System Reliability Using a Modular Decomposition, LAWRENCE D. BODIN, *IBM Washington Scientific Center, Wheaton, Maryland.*

FP4.10 Failure Rate Estimation From Censored Detection Data, GLEN BENZ, *Genge Industries, Inc., Sherman Oaks, California.*

FP4.11 Inference from Accelerated Tests when Observations are Obtained from Censored Samples, NOZER D. SINGPURWALLA, *Western Electric Company, Inc., Princeton, New Jersey.*

FRIDAY PM, MAY 3 ALAMEDA ROOM

Session FP5: 2:00–5:00 PM

Production Scheduling

Chairman: LOUIS W. MILLER

The RAND Corporation, Santa Monica, California

FP5.1 Optimal Allocation of Work in Production Line Systems With Variable Operation Times, FREDERICK S. HILLIER, *Stanford University, Stanford, California,* and RONALD W. BOLING, *University of Tennessee, Knoxville, Tennessee.*

FP5.2 Sequential Batch Scheduling in Multistage, Multichannel Systems, MICHAEL RESH, *Bell Telephone Laboratories, Inc., Holmdel, New Jersey.*

FP5.3 TOCOM—An Aid to Decision Making in Selection of an Operating Mode for a Multiproduct Facility under Conditions of Uncertain Product Value, J. W. CROACH, *E. I. du Pont de Nemours & Co., Wilmington, Delaware.*

FP5.4 Optimization of a Production System Response with Respect to the Input Characteristics, E. S. BAHARY, R. K. BHATTACHARYYA, *Western Electric Company, Princeton, New Jersey* and A. N. BAKHRU, *Celanese Corporation, Newark, New Jersey.*

FP5.5 A Planning and Control System for Disassembly-Assembly Operations in Meatpacking Plants, ROBERT C. MATTHES, *International Minerals and Chemical Corporation, Skokie, Illinois.*

FP5.6 An Efficient Algorithm for Multi-item Scheduling, L. S. LASDON, *Case Western Reserve University, Cleveland, Ohio,* and J. E. MACKEY, *Goodyear Tire and Rubber Company, Akron, Ohio.*

FP5.7 Analysis of Inventory Cost Parameters in Department Stores, M. D. SEVERSKY, *IBM Data Processing Division, White Plains, New York.*

FP5.8 Computer Job-Shop Simulation Model: A Decision Tool, F. D. KNIGHT and M. M. LUDEMAN, *E. I. du Pont de Nemours & Co., Aiken, South Carolina.*

FP5.9 Maintenance Policies in Markovian Multiservice Type Systems, ISRAEL BROSH, *Newark College of Engineering, Newark, New Jersey.*

FP5.10 Use of Simulation in Analyzing Optimal Maintenance and Replacement for Motive Systems in Railroad Operations, DONALD F. BLUMBERG, *WOFAC Corporation, Moorestown, New Jersey.*

FP5.11 A Simulation Model for the Allocation of Milking Equipment on a Dairy Farm, HARRY M. STRONG, *Bell Aerosystems Company, Wheatfield, New York,* and WARREN H. THOMAS, *State University of New York, Buffalo, New York.*

Abstracts

WA2.1. *The Role of Operations Research in Criminal Justice, ROBERT L. EMRICH, *Office of Law Enforcement Assistance, United States Department of Justice, Washington, D.C. 20530.*

The role which Operations Research is now playing in the Administration of Justice is discussed, along with suggestions for future applications for operations research. Some of the more significant and difficult problems facing an operations researcher in dealing with criminal justice system are discussed and illustrated, and recommended strategies for responding to these problems are suggested. The problems to be addressed include the definition of the objectives of the criminal justice system, the resolution of conflicts caused by the competition of objectives, the development of measures of effectiveness, the choice of the proper scale for early operations research projects in the area of criminal justice, and the choice of orientation appropriate to the needs of criminal justice.

WA2.2. *A Mathematical Model for Prediction of Police Patrol Workload, J. THOMAS MCEWEN, *Director, Resource Allocation Project, Board of Police Commissioners, St. Louis, Missouri*

In this paper a mathematical model which presently provides the management of the St. Louis Police Department with predictions of future workload in their various patrol areas is presented. These predictions have proven to be accurate enough to be employed in formulating patrol beats. In addition, queueing tables are being produced and used in planning operations. Based on predictions, these tables give an indication of the distribution of calls delayed if varying numbers of patrol units are available. The model assumes that the factors which influence the number of calls for service change slowly over a period of time. The prediction process is accomplished by maintaining distributions of calls over the hours of the week and the weeks of the year, and using this information in conjunction with exponentially smoothed averages on geographic subdivisions of the city.

WA2.3 *Classification Theory, Crime and Operations Research, PETER MACNAUGHTON-SMITH, *Center of Criminology, University of Toronto, Toronto, Canada.*

Classification may be seen as a paradigm of basic thought processes, since concept formation and handling are themselves forms of classification. Since operations research is often thought to be concerned more with decision than with understanding or conceptualization, some confusion can arise as to the areas of applicability of classification techniques. This can only be resolved by a deeper consideration of the relationship between operations research and other more explanatory science and also various nonscientific forms of thought and behavior,

* Invited paper.

of which art and magic may serve as examples. In other words, our own classification of all the ways of handling "data" available to humans may need to be sharpened or revised. Taking a superficial view both of crime and of operations research one might expect that certain predictive classification techniques would prove the most useful, since they are the most closely related to classical decision theory. In fact, rather "woollier" apparently criterion-free descriptive classification techniques seem to be just as useful even in apparently predictive situations. The extent to which this arises from features of the techniques, the real-life situations studied or the research attitudes brought to bear will form one possible starting-point for the discussion.

WA2.4. *A Feedback Model of a Total Criminal Justice System, ALFRED BLUMSTEIN and RICHARD LARSON, *Institute for Defense Analyses, 400 Army Navy Drive, Arlington, Virginia 22202.*

One central problem in improving law enforcement is the need to examine the total criminal justice system; comprising police, courts, and corrections agencies, in an integrated way. Any such analysis must reflect the feedback into society of offenders released at various stages in the system. In this paper, a model is formulated for the criminal justice system in one particular state. The model represents the flow of arrested persons through the system as a function of type of crime, and provides a basis for apportioning costs to system component and to type of crime. An important part of the model is the feedback feature, which reflects the probability of recidivism as a decreasing function of age, and a crime-switch matrix reflecting the successive-crime distribution. The results with the model include a cost distribution by crime type, criminal-career costs, an examination of the course of criminal careers, and an examination of the sensitivity of cost and offender flow within the system to changes in the system's controllable variables.

WA3.1 *Time-Sharing Systems for War Gaming Applications. ALBERT D. THOLEN and THOMAS A. THROOP, *Research Analysis Corportion, McLean, Virginia.*

This paper discusses two uses of time sharing systems for war gaming applications. The first is the operation in a time sharing environment of computer simulations of logistic systems. The possible interaction between a logistics planner and the computer permits the planner to study the sensitivity of the simulation output to changes in the input parameters. To assist him in the analysis, the planner during each iteration of the simulation may request for the simulation output only those outputs of particular interest. The second use is the development of computer programs displaying heuristic learning ability in a war game environment. The iteration of such a computer program with a "teacher" or "opponent" at a console makes it possible to assist the learning process of the computer program by "teaching" the computer program or by playing against the computer program. Both types of learning are important for a computer program which is to learn in a complex environment.

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WA3.2 *Current and Future Uses of Computer Time-Sharing in Business Gaming, F. WARREN MCFARLAN, *Harvard Graduate School of Business Administration, Boston, Massachusetts.*

The current use of computer time-sharing as an adjunct to business gaming in the MBA and Advanced Management Programs at Harvard Business School will be discussed. The accomplishments and frustrations to date will be reviewed with particular attention to the developments expected over the next several years.

WA3.3 *Management Use of Simulation in Long-Range Planning for Colleges and Universities, COLLIN W. SCARBOROUGH and JAMES N. DANIEL, JR., *Peat, Marwick, Livingston and Co., Boston, Massachusetts.*

The development of a computer model for simulating the programs and resource utilization of a university over the next ten years is described. The model is used to project department enrollment, curriculum demand, faculty utilization, physical plant utilization, and financial status under assumed environmental conditions and specified planning decisions. A major determinant of the model's effectiveness for university administrators is its implementation on a time-shared computer system for remote access operation. The continuity in evaluating alternatives provided through the rapid, iterative use of this model has proved a major benefit to college administrators using the model in a seminar environment.

WA3.4 *Why Time-Sharing?, JAMES RUDE, *The Pillsbury Company, South Minneapolis, Minnesota.*

The problems of getting management involved in time-sharing and simulation activities will be described. Particular attention will be devoted to several of the practical applications Pillsbury has made using simulation and time-sharing.

WA4.1 A Field Test of a Traffic Signal Setting Procedure, JOHN D.C. LITTLE, *Sloan School of Management, M.I.T., Cambridge, Massachusetts,* and STEPHEN B. MILLER, *Aerospace Corporation, Post Office Box 95085, Los Angeles, California.*

The traffic simulation model of Schwartz and the signal setting methods of Miller and Little have been applied to a specific problem: a 7 signal, 8000 foot section of West San Carlos Avenue, San Jose, California. This section has been highly instrumented by IBM and the city of San Jose and measurements of delay, stops, and flow are continuously taken. "Before" measurements were made under a specific fixed time setting of the signals. Parameters of the simulation were then chosen to make simulated delays and stops agree as closely as possible with the before measurements. A new fixed time synchronization of the signals was developed from the simulation by applying a univar improvement algorithm to an initial setting determined by maximal bandwidth methods. A calculated improvement of about 12.6% was achieved in the chosen objective function, which was a linear combination of stops per car and delay per car. "After" measurements were then made using the new settings in San Jose. The measured value of the objective function was 5.6% better than was found with original settings.

WA4.2 The Economic Optimization of Refuse Collection Operations, R. G. COYLE, *Harvard Business School, Cambridge, Mass.*, and M. J. C. MARTIN, *Bradford University, England.*

Most of the studies of refuse collection operations already performed by O.R. workers have been based on simulation. This paper describes an alternative, purely analytical, approach which has been developed to minimize the cost of refuse collection operations of a U.K. city of approximately 150,000 population. The method is completely general and applicable to a city of any size. A series of models are derived for refuse collection in varied housing layouts and it shows that all layouts may be reduced to one standard form. This standard form is then used to derive a model for the operations which is a function of collection teams, different team sizes, and the distance of the collection rounds from the refuse tip. Employing this model, a computational method is developed which allocates collection operatives to vehicles (using a dynamic programming approach) and designs collection rounds which together minimize the total refuse collection costs. The advantages of the method are: (1) it reduces refuse collection costs. In the city studied, it is estimated that costs will be reduced by approximately £10,000 ($28,000) per year, which is appreciably greater than the 'one-off' cost of performing the study; (2) it provides management with a convenient and efficient tool for planning total collection operations which can be easily amended as circumstances change.

WA4.3 Quantitative Decision-Making in Traffic Safety Management, DAVID M. BOODMAN, *Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts.*

Extensive efforts are being made at various governmental levels to promote the use of the methods of systems analysis in managing programs for the improvement of traffic safety. The extreme complexity of the traffic safety problem, its social importance and the tremendous economic cost of traffic accidents demand that the best management methods be used in dealing with this problem. The quantitative decision-making methods that are fundamental to a systems-analysis treatment of the traffic safety problem have been shown to be useful in dealing with certain portions of the problem. A selection of remedial measures for the cross-median accident suggests a number of system modifications capable of reducing the loss due to this class of accident. However, the quantitative evaluation of the alternatives poses a number of serious problems for the traffic safety manager. Failure or inability to deal with these problems may vitiate much of the value of the quantitative approach.

WA4.4 Recognition of Community Hazard Problems: The Systems Dynamics, B. C. SPRADLIN, *Georgia Institute of Technology, Atlanta, Georgia.*

This paper considers the design of policies for regional or community planning institutions and research programs to best bring to view whatever problem has potential to become a community hazard. A common systems structure that seems to surround the recognition of most community problems, whether they be health, crime, or pollution, is suggested. This structure considers regional planning

as it effects community laws or standards and public education and technology as it effects the measurement of the problem. Inertia effects and delays such as those due to tradition are also considered. A feedback systems perspective is taken toward structuring the system, and simulation experiments describing its behavior as it responds to certain regional planning policies for the particular problem of solid waste pollution are used as examples. The need for careful consideration in designing policy for control of problem recognition is evident when it is considered that it is this system that stimulates a community to seek a cure for the problem. In this sense control of recognition is the key to control of the problem.

WA4.5 Information Analysis Without States of the World, PETER C. FISHBURN, *Research Analysis Corporation, McLean, Virginia.*

A set of (terminal) acts is specified. For each act the decision maker is uncertain about what will happen if he implements the act. Models are developed to analyze the selection of optimal decision rules and an optimal experiment when there is no explicit effort to detail consequences or to formulate states of the world.

WA4.6 An Experimental Study of Risk Taking: Individual vs. Shared Payoff Gambles, EDWARD SUSSNA, and H. JEROME ZOFFER, *University of Pittsburgh, Pennsylvania.*

Subjects were asked to choose one of a pair of gambles. There were fifteen pairs; the expected value of the two gambles within any pair was identical, and positive in all cases. Differences in risk were held to be directly related to payoff variances. The subjects' conception of risk and their perceptions of differences in risk, as determined in a post-experiment questionnaire, were similar to those of the researchers. Subjects had opportunities to reveal their utility preferences on both an individual and shared payoff basis. In the latter case, the gambles were the same as before, except that a majority vote (within each randomly chosen five-man team) determined the choice of gamble. Participants were allowed to keep their winnings. The results showed a strong conservative bias (consistent with a minimum reject strategy), and reflected perhaps the special characteristics of a homogeneous set of business school subjects. However, in 14 of the 15 choices, significant shifts were made in the direction of risk, in going from individual to shared payoff decisions. Also, the subjects were more likely to abandon conservative choices where the alternative was a very high variance gamble.

WA4.7 The Relation of the Inducement and Contribution Processes to the Energy and Entropy Functions, CHARLES G. JACKSON, *Bloomsburg State College, Bloomsburg, Pennsylvania.*

The strategies in the exchange of utilities are assumed to be a contribution of anticipated value and an inducement of real worth for the employer, and an inducement of anticipated value and a contribution of real worth for the employee. Because of possible increments and decrements for both players, there are various permutations and combinations of 2 x 2 games. In these sub-matrices, some zero and some non-zero sum games result. Since the value of the game concept is

assumed to be an imputation for the zero sums, the average of the four numbers replaces the value of the game. The tests applied are adaptations of the wave characteristic of thermodynamics for monetary worth and the geometric jump of quantum theory for energy-entropy values. The resulting hypotheses suggest that rational behavior should be that the employer will keep utilities of inducement and contribution equal, and the employee should attempt to keep his contribution in slight excess of his inducement utility. The analogue of the cream separator suggests not only why the high energy worker will leave, but also why the employer will probably welcome this, as well as why the employer will be quite willing to tolerate the continued employment of the high entropy worker.

WA4.8 The Development of a State-Space Model of an Aerospace Enterprise and its Evaluation as a Practical Management Tool, RENE V. ELICANO, *Lear Siegler, Inc., Grand Rapids, Michigan.*

This study constructs a detailed mathematical model of the internal operations of an actual aerospace engineering and manufacturing enterprise. It uses a methodology originally developed for analyzing system models of electrical networks. This study evaluates the practical utility of this technique in assisting the business executive. Heuristic simulation is demonstrated thru the model. The model is found to be stable and state controllable. The control strategy to bring the firm to a desired state is shown. Considerable practical utility is found for both the methodology and the model. The methodology provides a convenient formal and generalized procedure for developing a model of the firm. The model has many managerial uses such as forecasting costs, load, resource requirements or cash flow and analyzing total impact of alternative decisions. The most promising facet of this methodology is its generalized analytical capabilities. As management pins down more of the true cause and effect relationships in the firm, the control strategy from the model will play an ever-increasing role in guiding their key decisions.

WA4.9 A Technique for Appraising Technical Progress, A. T. STEELE and ROSA M. BODENHAMER, *Sandia Corporation, Albuquerque, New Mexico.*

"How are we doing?" Every manager must ask this question and take action on the basis of what he *thinks* is the answer. The technique to be presented for appraising technical progress inludes analysis of actual accomplishment vs. planned accomplishment and actual cost vs. planned cost. Now it is possible—with computers having real time capability and large on-line data storage—to make information available soon enough to do something about it. The appraisal technique presumes a project plan which defines input in terms of resource packages and related costs over periods of time. It also defines expected resultant output over the same periods. Data regarding actual cost can be collected on a current basis for comparison with planned cost when needed. Actual accomplishment, however, can best be measured at milestone points where a defined phase of the project is completed. Here, by comparing points on a planned progress curve and on the related actual progress curve, it is possible to answer both questions: "Are we behind schedule?" and "Are we overspent?" On these two special type

curves one can evaluate both technical and cost performance. The main part of the presentation is an analysis of the graphical technique for evaluating these two special curves. This work was supported by the Atomic Energy Commission.

WA4.10 Marketing and Equipment Utilization Planning, NORMAN T. ELLETT, and RICHARD K. DAVIS, *Fry Consultants, Inc., 3540 Wilshire Boulevard, Los Angeles, California.*

This paper deals with marketing and equipment utilization planning in the shipping industry. The purpose of such planning is to provide a means for maximizing profits within the constraints imposed by the marketing effort and availability of equipment. It is believed that the technique developed can be applied to a wide variety of industrial problems where formalism of the market structure is possible. This technique is already in use by one shipping company. In order to maximize profits, it is first necessary to design an acceptable equipment utilization plan which in the case of the shipping industry involves the deployment of freight carrying ships. The utilization plan must be measured against constraints imposed by the market place. If the utilization plan falls within the constraints it is temporarily accepted. Then a better (more profitable) plan is sought and measured against the constraints until no better plan can be achieved—or until patience gives out. In the case of the shipping company the heuristics are developed through a dialogue between the marketing and operations department. A computer simulation has been programmed for producing a fleet utilization plan which measures marketing effectivenss as well as total fleet profitability. This plan is then compared against the most profitable plan previously developed. If the new plan indicates potentially greater profits than the previous best plan and lies within the marketing constraints, the new replaces the old, and so on. The quantification of the market constraints becomes extremely critical to the successful employment of this process. The finally selected utilization plan becomes the basis for the marketing plan in order to optimally allocate the marketing effort over the planning period.

WA5.1 Use of Mathematical Programming in Sensitivity Analysis of Allocation of Various Crude Oils in Refineries, PREM K. MUNJAL, *System Development Corporation, Santa Monica, California.*

It has been shown that sensitivity analysis through mathematical programming provides a very powerful technique in determining the optimum operating plan in face of various uncertainties in the given input data. The method is illustrated by formulating the problem of allocation of crude oils in refineries. Problems were formulated for linear and nonlinear cases and their optimal results were obtained by formulating several mathematical models, which were solved by hand and computer computations. Sensitivity analysis of the above mathematical models were then performed to determine the effect of a single and simultaneous variation of the crude compositions, crude net backs, errors in laboratory experiments, optimality range of the optimum solution, new crude availability, crude supply ratios from the independent producer and the refinery distillation capacities. Sensitivity analyses were also performed for several nonlinear cases which were

incorporated into the mathematical models through a separable programming algorithm. Some of the nonlinearities included the nonlinear relationships of crude costs, pipeline capacities, crudes availability ratios. It is suggested that better results from sensitivity analysis are obtained by better communications and coordinations between the engineers and the operations analysts.

WA5.2 Iterative Quadratic Programming in Activation Analysis, LEE H. SMITH, *Associate Dean, The University of Texas at Arlington.*

Various statistical techniques have been employed in "activation analysis" in order to provide a better means of estimating amounts of various pure chemical elements contained in an unknown mixture. Specifically, the method of least squares has been employed extensively. However, for the most part, usual least squares applications have utilized the ordinary matrix model $Y = X\beta + e$, under the "error" assumptions (a) zero means, (b) variances proportional to Y, and (c) zero covariances. In addition to the fact that assumptions (b) and (c) may lead to erroneous results, previous applications allow only point estimation, with no provision for confidence intervals and tests for model goodness to fit. Further, usual applications fail to eliminate the drawback that negative coefficients are sometimes obtained. The present paper sets forth an iterative quadratic programming estimation procedure which not only eliminates the necessity for assumptions (b) and (c), but also alleviates the other above-mentioned difficulties. Although the classical theory of both least squares and quadratic programming is used as a guide to suggest appropriate estimators, no reliance is made on the classical theory of linear models for the distribution properties of such estimators. For the latter a special technique of variance estimation has been developed.

WA5.3 A Mathematical Programming Approach to the Scheduling of Experiments in Space, PAUL R. REBELEIN, PETER M. TREUENFELS, *Honeywell, Incorporated, 2600 Ridgeway Road, Minneapolis, Minnesota,* and E. F. FLEISCHMAN, *National Aeronautics and Space Administration, Marshall Space Flight Center, Alabama.*

Historically, experiment scheduling problems have been solved by trial and error methods which usually result in feasible but not optimal schedules. In order to circumvent this obvious shortcoming, a mathematical programming algorithm, employing integer linear programming, has been developed to schedule experiments in such a manner that the benefit derived from a space mission is maximized. At the same time, the algorithm is capable of solving the experiment selection problem. This paper discusses the algorithm, the structure of the integer linear programming problem, a mathematical model that generates some of the logical constraints, and the limitations of the mathematical programming approach. Some, but not all, of the features of the algorithm have been programmed in Fortran IV and applied to a trial AAP mission consisting of one orbit. The results, which are also presented, indicate that the approach is both feasible and practical.

WA5.4 A Multi-Valued Evaluation of the Effectiveness of BMD Deployments by Mixed-Integer LP, RICHARD C. MOREY, *Stanford Research Institute, Menlo Park, California.*

Most analyses of defensive missile deployments have been directed at investigating a single measure of effectiveness, be it lives saved, gross manufacturing capacity surviving, etc. And yet, beyond bare survival, the issue of national viability depends to a great extent on the simultaneous availability to various levels of many individual personnel and manufacturing resources. In order to adequately take into account the multi-valued aspects of this problem, a mixed-integer linear programming model was used which, in the face of a given defensive deployment, generates the minimal attack which renders the defended country inviable; this inviability is defined in terms of the defended country's inability to meet some minimal list of consumer requirements. In this formulation, the integer variables are related to the decisions of which particular defenses to attack, and to which of the many individual resources the attacker should optimally key on; the continuous variables correspond to the actual attack levels, given the specific defenses and the resources to be attacked. The main value of the model is that, by combining input-output techniques with a damage assessment, one can uncover potential Achilles' heels in the defended country's economy. Actual computer runs will be discussed.

WA5.5 The Application of An On-Line Integer Programming Code to Computer Assisted Menu Planning, C. RALPH BLACKBURN II and JOSEPH BALINTFY, *Tulane University, New Orleans, Louisiana.*

A multiple choice programming model developed by the authors has been successfully applied to computer assisted menu planning and has been implemented in several institutions. The menu planning model uses a cost minimization algorithm in a multi-stage framework producing a sequence of menus satisfying daily constraints of nutrition, variety, palatability, etc. Modification of contraints is allowed on-line in each stage. A special group of binary coded set constraints based on the concept of vector orthogonality represents various management policies. These as well as other coding innovations are described which reduce the effective matrix size and improve speed characteristics allowing a relatively large problem to be solved quickly in core in an IBM 7044.

WA5.6 A Linear Programming Evaluation of Institutional Management Policies, LYMAN C. DENNIS and JOSEPH L. BALINTFY, *Tulane University, New Orleans, Louisiana.*

One of the determinants of the success of an institution O.R. application is the extent to which management policies as embodied in the model are subject to evaluation and control. In institution menu planning by linear programming, policy evaluation is facilitated by the model itself. The authors report on experience gained by the application of an upper-bounded linear programming system using nutritional, structural, attribute, and upper bound constraint sets to represent the food service decisions of several hospitals. Through the techniques of (1) post optimality marginal analysis, (2) policy set marginal analysis, and (3) cost-

benefit reoptimization analysis, menu planning policy is evaluated and the resulting feedback to management is used as a mechanism to reveal and control institutional tendencies toward suboptimization.

WA5.7 The Planning of Pipeline Networks, JOHN A. SPENCE, *W. D. Scott & Co. Pty. Ltd., 37 Mount Street, North Sydney, N.S.W, 2060, Australia.*

The problem in pipeline network planning of establishing the optimum programme of investment in plant and facilities to transport resources from fixed locations to meet time varying demands at remote centres is one of considerable complexity. It involves the simultaneous consideration of the various elements of the possible network of pipelines with non-linear cost-capacity characteristics, joining diverse fields with differing reserves, development costs, and permissible withdrawal rates to demand centres with maximum and average demand rates. The objective is to minimize the discounted cost of pipeline installation and operation while providing for alternative means of increasing pipeline capacity. In this paper the problem is formulated as a large integer programming problem beyond the capacity of available computer programmes. A practical computational procedure is developed using linear programming and integer programming which, by an iterative process, leads to a close approximation to the optimum solution. Actual problems have been solved selecting from 20 pipelines connecting 6 fields and 4 markets. However, the main uses of the model as developed are seen to be to establish the importance of changes in the network or in environmental conditions, as for example, due to the impact of the discovery of a new field, or the development of a new market.

WA5.8 A Branch and Bound Algorithm for a Strategic Deployment Model in Which Aircraft Productivity Depends on Aircraft Mix, DONALD GROSS, *The George Washington University, Washington D.C.*, and RICHARD M. SOLAND, *Research Analysis Corporation, McLean, Virginia.*

The branch and bound algorithm developed in this paper is used to solve a strategic deployment model in which some constraint coefficients depend upon the values of certain decision variables. Were it not for these dependencies, the model could be solved by linear programming. Specifically, aircraft productivity values, which appear as coefficients in a number of constraints, exhibit nonlinear relationships with aircraft mix, i.e., the ratio of type 1 to type 2 aircraft used on a particular route. These relationships are first approximated by piecewise linear functions. A branch and bound algorithm for solving the resultant model is then presented; the algorithm solves a sequence of linear programming problems. The algorithm is illustrated by a sample problem and comments concerning its practicality are made.

WA5.9 Optimal Capacity Expansion, G. T. HOWARD, *U.S. Naval Postgraduate School, Monterey, California,* and G. L. NEMHAUSER, *Johns Hopkins University, Baltimore, Maryland.*

Given an arbitrary finite sequence of demands $s_N \cdots, s_1$ and an intitial system capacity (size) c_N, an algorithm is developed to solve the capacity expansion prob-

lem: $\min_{d_n} \sum_{n=1}^{N} [p_n d_n + g_n(s_n, c_n)]$ subject to the constraints $d_n \geqq d_n^-$, $c_{n-1} = \theta_n c_n + a_n d_n$, where c_n is the capacity of the system at time period n, d_n is the investment decision, a_n is a techno-economic coefficient relating investment to change in capacity, p_n is a unit investment cost, θ_n is a depreciation factor, and g_n is a strictly convex differentiable function of c_n reflecting costs of insufficient and excess capacity. Note that demand does not deplete capacity in this model. The algorithm is extended to treat stochastic demands, a constraint on total investment, upper bound constraints on individual investments, constraints on capacity, cost discounting and a piecewise linear relation between investment and the change in capacity. Finally, the algorithm is generalized to treat certain cases in which there are M classes of demand, one for each of M different systems which are to be expanded. The relation between the capacity expansion model and some dynamic inventory models is discussed.

WA5.10 Dynamic Programming for Feedlot Optimization, CARL F. MEYER, *Department of Applied Mathematics and Computer Sciences, Washington University, St. Louis, Missouri,* and ROBERT J. NEWETT, *Operations Research Group, Ralston Purina Company, St. Louis, Missouri.*

Optimal operation of enterprises engaged in slaughter animal production entails determining 1) what initial weight animal should be purchased; 2) the final selling weight; 3) the length of completion time; 4) the number and length of feeding periods within this time; 5) what ration and its quantity should be fed in each of these periods; to balance feed costs, purchase cost of feeders, and time-dependent fixed costs such as yardage, handling, maintenance and interest against market selling prices in such a way as to maximize total profit. The model presented uses dynamic programming to perform precisely this task, and is structured so as to be functionally independent of any feed consumption weight gain relationships, making it adaptable to feeding operations for any type of animal. This development precludes any past attempts to optimize isolated parts of the problem; by considering all pertinent variables, time-dependent and not, it effectively maximizes total profit for any type of feedlot by simultaneously optimizing all phases of the operation. The model is an ideal application of the principle of optimality, making liberal use of the characteristic of dynamic programming to solve complex time-sequenctial decision problems with separable objective function and highly nonlinear recursive constraints.

WA5.11 On the Optimal Cutting of Defective Glass Sheets, SUSAN G. HAHN, *New York Scientific Center, IBM Corporation, 590 Madison Avenue, New York, New York.*

A method is developed to cut up glass sheets with defects into given pieces by minimizing waste The sheets, the pieces and the defects are all rectangles, the latter to be identified by the coordinates of two opposite corners in a coordinate system attached to the sheet. The cutting is done in three stages. If the length of the sheet is along the x-axis, the first cuts are made parallel to the y-axis, obtaining "sections." The sections are then cut into "strips" parallel to the x-axis, and finally the strips into "lites" parallel to the y-axis. The procedure uses the

theory of knapsack functions, as developed by Gilmore and Gomory, which is basically a dynamic programming approach. To each required size a "value" is attached which is some, preferably nonlinear, function of the area. The computer program senses the defects and fits lites into the clear portions of the sheet in such a way that the total value is a maximum. In order to shorten machine time some simplifying short-cuts are made.

WA6.1 The Allocation of Defensive Fire, DANIEL O. ETTER, JR., *Systems Evaluation Division, Institute for Defense Analyses, Arlington, Virginia.*

Consider the allocation of defensive fire against an assault column. Assume that the attrition can be described by processes of deterministic Lanchester type. What form do the optimal allocations take, and how much does the defense gain by exploiting them, rather than (say) a uniform allocation of fire? We answer these questions under the assumption that the distribution of force in the attack column has attained a stationary value. We consider three basic attrition processes: (1) Square law, assuming units are not concealed; (2) Linear law with aimed fire, the rate controlled by the rate of detection of attackers; and (3) Linear law attrition arising from barrage fire. We also consider two possible defense objectives: (1) maximum attrition of the attackers, and (2) maximum survival of the defenders. We find that, in many cases, each unit has a preferred target. However, allocations can deviate considerably from the optimal without leading to undue loss of effectiveness.

WA6.2 Stochastic Duels with Markov Dependent Kill Probabilities, C. BERNARD BARFOOT, *Center for Naval Analyses, Arlington, Virginia.*

This paper presents some further developments in the theory of stochastic duels for situations in which the kill probability of each contestant is not constant for each round fired, but is dependent on the outcome of the previous shot and only on the previous shot. In these duels both contestants are assumed to have an unlimited supply of ammunition, to fire at either constant or randomly varying intervals of time, and to duel until one is killed. For these conditions, the probability of a given side winning the duel is given for the case where (1) both contestants begin with unloaded weapons and have tactical equity, and (2) one contestant has the advantage of surprise and can fire y rounds at the other before the two-sided duel begins, where y is a random variable with known probability distribution. Potential applications of models of this type to duels between weapons are illustrated, and further areas for research are discussed.

WA6.3 An Input-Output Approach to the Selection of Industrial Target Sets, JOHN MCCORD, *The Boeing Co., Seattle, Washington.*

In any attempt to evaluate the effect of strategic bombing on industrialized economies, a vital requirement of the analysis is that it should consider the strong interdependence between elements of such economies, since often this interdependence may cause the secondary effects of attacking a particular set of targets to be stronger than the primary effects. A linear programming model of an industrial economy has been developed which uses a variant of input-output analysis

to take account of this interdependence. The model also considers other important features of an economy under stress, such as the ability to change production methods and to reallocate resources. By using parametric programming on activities in the model corresponding to the destruction of primary productive resources, it is then possible to derive target sets composed of specific industrial sectors, whose degradation will give the greatest reduction in the economy's war potential for any given attack level.

WA6.4 Extensions of the Tanker Scheduling Problem, M. BELLMORE, *The Johns Hopkins University, Baltimore, Maryland,* G. BENNINGTON and S. LUBORE, *The Mitre Corporation, Arlington, Virginia.*

Two modifications to the Dantzig and Fulkerson Tanker Scheduling Problem are described. First, an insufficient number of vehicles and a utility associated with each vehicle delivery are assumed. We seek a schedule which maximizes the utility of vehicle deliveries made. The new problem is shown to be equivalent to a Transshipment Problem. Second, we assume a fleet of vehicles with different characteristics. We treat this Multi-vehicle Type Tanker Scheduling Problem using extensions of the techniques derived from the first modification.

WA6.5 A Satellite System Optimization Model, KARL SEILER, *Communications Satellite Corporation, 1900 L. Street, N.W., Washington, D.C.*

A prime consideration in satellite system design is the minimization of the combined earth and space segment investments subject to a performance constraint. A system optimization model is described which uses triangular distributions of the key system parameters. Expected values of system optima are derived for a range of satellite powers, earth station powers and circuit capacities. A ten-percent dispersion in the optimum values can be expected based on the distributions of the inputs. A sensitivity analysis revealed that a non-optimum configuration could result in increasing the total system cost by as much as a factor of two.

WA6.6 Information System for War Games, JOANN LANGSTON, *Technical Operations, Incorporated, 101 Lincolnia Road, Alexandria, Virginia.*

There exists a requirement for a data management system for use in computer assisted war games where assessments are performed by computer simulation and manually judged and acted upon by the players. This requirement arises from the quantity and diversity of data used in a game, from the necessity for data which is current and applicable to the time frame in which the game is played, and from the need for the assessment models to use some data specific to a particular model plus other data common to more than one model. This paper describes a recently developed system for the design and implementation of automated procedures for acquisition, retrieval, manipulation and dissemination of game data. The system provides a repository for data required during pregame analysis and the initiation of a game, provides for finding, positioning and storing the data as required at the end of each assessment cycle, provides for recording the results of the assessment

models, and finally, provides data and routines for analyzing the game results at the end of a cycle, period, or completed game. Applications of the methodology are discussed.

WA6.7 SAMMIE—Scheduling Analysis Model for Mission Integrated Experiments, MICHAEL G. BRUNSCHWIG, SPENCER BULLARD, and JOHN L. SANDEN, *Martin Marietta Corporation, Denver, Colorado,* and NEIL B. HILSEN, *Bendix Corporation, Teterboro, New Jersey.*

Experiment performance requirements must be scheduled within the many constraints of the spacecraft resources, orbit position and crew availability. SAMMIE is a computer model designed as an aid in the scheduling of manned space missions. The logic closely follows those techniques used to schedule experiments by hand. Some of the more important scheduling considerations include: 1) performance before, after, or with another activity; 2) performance at specific times or on certain days; 3) performance by certain astronauts in a specific sequence; 4) variable performance times with variable repetition intervals; 5) setup and stowage of experiments. The experiments are scheduled in sequence, starting with the experiment most difficult to schedule. The assumption is made that all experiments specified for the mission must be scheduled. SAMMIE attempts to schedule all the experiments input to within a given packing percentage. Most scheduling models determine which experiment to schedule by examining each event time chronologically. SAMMIE selects each experiment and searches the mission timeline for the experiment's correct or proper time slot. Output schedules include all crew activities in a digital format as well as a computer generated plot which includes day-night cycles, over station times, spacecraft operations and an experiment performance timeline. SAMMIE is written in Fortran IV for the CDC 6400.

WA6.8 Advanced Planning For Command and Control Systems, MICHAEL W. LODATO, *McDonnell Douglas Corporation, Huntington Beach, California.*

A methodology is outlined in which conceptual models of Command and Control (C&C) systems that will be required in the future can be developed on a continuing basis. The methodology includes the full spectrum from projections of future world states to an approach to identification of each element of future C&C systems down to the processor level. It allows for the current heavy emphasis on evolutionary development of command systems using existing systems as a base, and relates and synthesizes state-of-the-art studies, mathematical modeling activities, mission analyses, decision structure analyses, conceptual modeling tasks, and concept-of-operations determinations. The methodology, which, in essence, represents a tool for planners involved in concept formulation activities, will be presented in the context of its use in formulating tactical command and control concepts.

WA6.9 Decentralized Planning in the Naval Supply Systems Command, ROBERT D. SCHULTZ, *Planning Division, Naval Supply Systems Command, Main Navy Building, Washington, D.C.*

The Naval Supply Systems Command has the responsibilities for direct administration of many activities and for providing management policies and tech-

nical guidance for Navy-wide material management. The changing relations over time between various logistics factors require that planning be done to continually provide adequate levels of system capability. The responsibility for generating planning alternatives is decentralized throughout the Headquarters organization while the centralized planning division provides the structure of the planning discipline, analytic capability, and a continual awareness of the needs and importance of planning. A *problem/opportunity management system* is used to obtain a *structure of purpose*. The structure of purpose is the organization plan for the future. The various capabilities of the future organization are stated as specific objectives with a substructure of goals and tasks. These specific objectives and their substructures translate the vagaries of a single mission statement and several general objectives into achievable, desirable, and real material management capabilities. The problem/opportunity system provides the uniform discipline where possible existing or future problems are identified as needing Headquarters attention and plans for achieving solutions are developed and made part of the specific objectives structure and put into motion. The discipline is described and progress in using this methodology is discussed.

WA6.10 Bombing Problems, III, ANDRE G. LAURENT, *Wayne State University, Department of Mathematics, Detroit, Michigan.*

Let $\mathbf{X} = (X_1, X_2)'$ be the coordinates of a point of impact and let $\mathbf{m} = (m_1, m_2)'$ be the target. It is commonly assumed that $\mathbf{X}$ has a normal distribution, which is circular or not circular. The present paper considers the case when $\mathbf{X}$ has a "circular" or an "elliptical" distribution $f(\mathbf{x})$ which is not necessarily normal. The general properties of such distributions are studied in detail. Each distribution $f(\mathbf{x})$ is in one-one correspondence with and readily obtained from the distribution of $g(r)$ of the error R, where $R^2 = (\mathbf{X} - \mathbf{m})' (\mathbf{X} - \mathbf{m})$. Plausible hypotheses are made on $g(r)$ and the corresponding models for $\mathbf{X}$ are studied from the viewpoints of probability and statistical inference.

WA6.11 A Countdown Decision Aid, L. R. GUTSTADT, *Space Division of North American Rockwell, Downey, California.*

This report presents the conceptual development of an information storage, retrieval, analysis and display system. The system is usable by launch control center personnel, primarily during a countdown. The program has been conceptually derived to aid rapid decision making during a countdown when an anomaly occurs. The report contains four sections. The first section on functional analysis provides additional background, describes operational details of the proposed system and discusses usage problems plus a requirements analysis. The second section on computer capabilities details the computer problems and relates the Countdown Decision Aid to Kennedy Spacecraft Center. The third section discusses the timing and probabilistic relationships to be employed. The last section on cost effectiveness provides a method for estimating cost and effectiveness values and shows how they may be combined to evaluate various systems.

WP1.1 Dynamic Programming under Piecewise Linearity Assumptions, REUVEN AMIR, *The Service Bureau Corporation, Bay Area Scientific Computer Center, Palo Alto, California.*

A large class of dynamic programming problems involves, at each stage, the determination of a function $h(x)$ and a mapping $y^*(x)$ defined by the relationship:

$$h(x) = \min_y \{f(x - y) + g(y)\} = f(x - y^*(x)) + g(y^*(x)),$$

where x, y and y^* are n-dimensional vectors, y and x being restricted respectively to the sets P and S. The vectors x and y can be regarded as arrays of resources available before and after the amounts consumed during the current stage, and y^* is the optimum value of y. The function f represents the immediate benefits from presently consuming the amounts $x - y$, and $g(y)$ denotes the future expected benefits under optimum allocation at each future stage. The present paper investigates properties of the mapping $y^*(x)$ when $f(x - y)$ is convex and piecewise linear in $x - y$. It turns out that in this case the set S can be divided into a number of subsets of positive measure which facilitate the evaluation of $y^*(x)$. Some of these subsets are characterized by the fact that the value of $y^*(x)$ for a single value of x in such a subset uniquely determines the subset itself and the values of y^* for all states x in the subset. Other subsets of S are infinite collections of m-dimensional sets, $m < n$, each such set having the property described above. All the m-dimensional sets in one such collection are parallel translations of one known "generating" set. Thus, piecewise linearity of f may lead to a considerably reduced computational effort when solving this type of dynamic programming problem.

WP1.2 Quadratic Binary Programming With Application to Capital Budgeting Problems, D. J. LAUGHHUNN, *University of Illinois, Urbana, Illinois.*

The purpose of this paper is to present on algorithm for solving a quadratic programming problem having the form: min $X'CX$ subject to the constraints $AX \leqq B$ and X_j either 0 or 1 where C is a positive semi-definite $n \times n$ matrix, A is an $m \times n$ matrix, and B is an m-component column vector. Although this problem may arise in many situations, it is particularly common in capital budgeting when a decision-maker is confronted with a set of n investment proposals, from which he must select a portfolio, with $X_j = 1$ denoting acceptance and $X_j = 0$ denoting rejection of proposal j respectively. If the returns of the proposals are intercorrelated random variables and if the decision-maker uses as his criterion the mean (μ) and variance (σ^2) of portfolio returns, his decistion requires prior identification of the (μ, σ^2) efficient set. Interpreting the C matrix as the variance-covariance matrix of portfolio returns, generation of the (μ, σ^2) efficient set reduces to a solution of the above quadratic programming problem for a parametric variation in the minimum acceptable return (μ). The algorithm developed to solve this problem is based on the concept of implicit enumeration recently introduced by Egon Balas for solution of the binary linear programming problem. Some of the exclusion tests for branch abandonment take advantage of the special structure of the capital budgeting problem, i.e., the existence of mutual exclusive and

conditional project proposals. A heuristic gradient procedure is used to determine an approximate solution to the problem which serves as an initial starting point for applying the algorithm.

WP1.3 A Turnpike Theorem for Undiscounted Markovian Decision Processes, PAUL J. SCHWEITZER, *Institute for Defense Analyses, Arlington, Virginia.*

We show that, if all policies which achieve the maximal gain rate vector are aperiodic, then policies which achieve the maximum in the value-iteration equations

$$\max_{1 \leqq K \leqq M_i} \{q_i^K + \textstyle\sum_{j=1}^{N} p_{ij}^K V_j(n)\} \qquad 1 \leqq i \leqq N$$

for sufficiently large n all achieve the maximum gain rate vector. This provides a rationale for using maximal-gain policies when the termination horizon is finite but distant, complementing a similar result obtained by Shapiro for the discounted case. The hypothesis also guarantees the asymptotic behavior

$$V_i(n) \to ng_i + V_i \qquad 1 \leqq i \leqq N,$$

extending previous results by Brown on value-iteration.

WP1.4 A New Approach of Solving Zero-One Linear Programming Problems, D. K. GUHA, *The Port of New York Authority, New York, New York.*

Integer programming problems involving zero-one variables only have been solved with some success by E. Balas, Fred Glover, etc. A method different from theirs is being presented here. The problem is put in the following form: Minimize cx subject to $Ax \geqq b$, $x_j = 0$ or 1 for each j, where c, A and b have their well-known interpretations. The method starts with finding inverse constraints for each of the variables x_j from $Ax \geqq b$. Initially all x_j's are put equal to zero, and values are computed from the right-hand side of the constraints for x_j's. The present algorithm then looks for those variables from the constraints for x_j's which should be raised to 1 to make presently infeasible x_j's feasible. Finally, a feasible solution is obtained if it exists; otherwise the algorithm indicates that the problem has no feasible solution. Improved solution is easily obtainable by solving a similar problem after adding a constraint obtained from the objective function based on its present value to the system of constraints. If the resulting problem is found infeasible, the optimal solution of the problem is given by the preceding feasible solution.

WP1.5 A Generalized Material Simulation System, CHARLES E. DONAGHEY, *Cullen College of Engineering, University of Houston, Houston, Texas.*

Material handling systems have been found to follow a general model consisting of moves and equipment required to execute these moves. The model is described and a computer program of the model is explained. The computer program is written in FORTRAN to allow for universal usage. To utilize the program the user furnishes data parameters concerning his material handling system and the

program will simulate the system. Proposed changes in a material handling system can easily be tested. The program has been tested in two industrial situations and the results are reported.

WP1.6 Digital Simulation of Large Communications Networks, EDWARD H. COOPER, *Defense Communications Agency, Washington, D.C.*

This paper deals with the technique of using large scale digital simulation in the analysis of the performance of communications networks. Data collection procedures used, models developed, and the preparation of output data will be described. The systems analysis procedure developed will be illustrated by discussions of actual networks that have been simulated. The impact of simulation languages, hardware available, and model development times will also be included. Management procedures required to utilize efficiently such a program will be included in the paper.

WP1.7 A Dynamic Approach to Cost-Effectiveness, R. O. KIDD, *TRW Systems Group, Redondo Beach, California.*

This paper presents a technique for determining the values of design parameters and system support policies that maximize system effectiveness as functions of total program cost. The technique employs the Lagrange formulation of the calculus of variations. This approach is dynamic in the sense that it maximizes effectiveness as a function of cost; in contrast to this, present techniques are static in the sense that they maximize effectiveness for a fixed cost or minimize cost for a fixed level of effectiveness. The dynamic technique provides the executive or customer with considerably more information upon which to base major design and support decisions. This approach is applicable in the concept formulation, preliminary design and development phases of a program. The paper formulates the cost-effectiveness problem in terms of the classical calculus of variations. The development of necessary and sufficient conditions for an optimal solution is presented. The paper includes a description of the method of numerical solution and several simple examples to clarify the formulation.

WP1.8 A Parametric Programming Approach to Cost Benefit Analysis, CHAIHO KIM, *University of Santa Clara, California.*

First, this paper will extend the theory of parametric linear programming in the following respect. It will examine the relation between a variation in the value of the parameter for the requirement vector and that of the parameter for an activity vector in an optimum basis. In doing so, it will establish a method of finding the amount of variation required to bring about an end result which is equivalent to what would be obtainable if the value of the other parameter were varied by a given amount. Second, the paper will explore the applicability of the methodology developed above for certain types of cost benefit analysis problems. As an example, it will consider a decision problem that demands a choice between an increase in the capacity of a productive facility and an increase in the productivity of that given facility or some mixture of the two where the cost functions of the alternatives are known. It will be shown that the alternative which will entail

the minimum cost per dollar of the incremental benefit can be determined by letting the increase in the capacity and that in the productivity be functions of the two parameters corresponding to the requirement and activity vectors respectively and then converting the changes in the values of these parameters into mutually commensurate measures in terms of the benefits to be reaped.

WP1.9 Management Decision Utilizing Cost-Effectiveness Modeling, IRWIN NATHAN, *Xerox Corporation, Webster, New York.*

In this paper an example of how the "specifics" of a major subsystem are related to the decision rules developed from cost-effectiveness considerations are demonstrated. An extensive study of a subsystem for an advanced ship deployment system was conducted to select the cost-effective subsystem and specify the procurement parameters from many attractive subsystem alternatives. It is shown that for a subsystem whose performance does not limit the productivity of the primary system (achieves minimum productivity), the measure of effectiveness is lowest life cycle cost (LCC). Since only minimum productivity is needed for the lowest LCC, any expenditure which results in getting increased subsystem productivity is both unwarranted and irreconcilable with proper cost-effectiveness concepts as applied to subsystems. The lowest LCC subsystem alternative is shown capable of meeting minimum productivity requirements by parametrically analyzing (curves and program included) the Cost-Effectiveness model. The productivity of the subsystem during the mission is a function of: 1) Equipment state at mission start (includes "under repair" states); 2) Mission dependability; and 3) Subsystem performance by equipment state. The subsystem meeting minimum productivity requirements and lowest LCC was identified and became the management choice.

WP1.10 Systems Analysis Approach to the Creation of Mathematical Models to Predict Highway Maintenance Costs, LAWRENCE MANN, JR., *Louisiana State University, Baton Rouge.*

Each year state legislatures are called on to appropriate ever-increasing funds to maintain the state-maintained roadway system. In addition, the Federal Government is building the 40,000-mile Interstate system on the presumption that the states will assume the maintenance costs of that system. In most cases the highway personnel cannot justify their requests to legislatures for funds in terms of what the system *should* cost. The research which this contributor describes is one state's attempt at writing a series of models to predict what funds should be allocated to this effort. Problems such as quantification of level of maintenance, of maintenance adequacy, of roadway surface condition, etc. are defined and the researcher's approach to the solution of these problems is described. The analysis of the roadway system, from the maintenance standpoint, requires some creative design in quantification of variables as well as the use of the transitional statistical and operations research techniques to solve problems which are part of a complex system. The research began in 1962 and, as yet, satisfactory solutions have not been found to all problems. It is hoped that this discussion will bring to light some novel approaches.

WP1.11 Travel Time Through Successive Traffic Signals by a Mathematical Procedure, W. R. BELLIS, *New Jersey Department of Transportation, 1035 Parkway Avenue, Trenton, New Jersey.*

This paper describes in detail a mathematical procedure measuring the travel time in each direction through a series of traffic signals considering the following variables: (1) number of signalized locations, (2) the spacing of these locations, (3) the timing of each signal, (4) the offset of each signal, (5) the speed of vehicles, (6) the acceleration characteristics of vehicles, and (7) the volume of traffic. For a given set of signalized locations, all of these variables are fixed; then, by varying offsets, calculations will determine the travel time through the system for the average car in both directions. By testing all possible variations of offsets, the set producing the minimum travel time for both directions can be had. There was a very close agreement between a field test and calculations through a nine-mile section with 29 signals having spacings varying from 270 to 9,000 feet. Although this procedure is mathematically sound, we have not been able to examine it for minimum travel time. It is quite possible that others may be able to supply the missing link so that the set of offsets can be selected producing the least travel time. Without this, it is always possible that another set of offsets may produce a shorter travel time.

WP1.12 Maximizing Total Traffic Flow in a Parallel Street System With Freeway Access Constrained by Metering, CAPTAIN GERALD L. ANDERSON, *United States Air Force,* and GLEN D. SELF, *Texas A&M University, College Station, Texas.*

This paper presents the general formulation and solution for the problem of optimal metering of traffic onto a freeway from a service road with any number and type of entrance and exit configurations. The solution utilizes dynamic programming which overcomes a number of disadvantages and limitations of the linear programming approach to this problem. This solution is able to account for the total flow through the system on the primary and secondary corridors, thus maximizing the combined flow. Other realistic characteristics of the solution for practical traffic control purposes are (1) the consideration of congestion on the service road due to traffic leaving the freeway, (2) the consideration of congestion of the service road due to cross traffic, (3) the consideration of balking due to units being denied access to the freeway which may cause them to leave the system to seek an alternate route, (4) the use of non-linear functions to relate flow to traffic density, and (5) the use of a realistic approach to utilization of computerized sensing and near real time metering of entrances to freeways. Examples of various degrees of freeway service road complexity are presented. A dynamic programming formulation and example solution are provided for each general case. A FORTRAN IV computer program for general problem solution is included as an appendix to the work.

WP1.13 Computerized Corporate Planning Model, JOSEPH K. FURST, and MARVIN H. PORTER, *Financial Planning Section, Philadelphia Electric Company, 1000 Chestnut Street, Philadelphia.*

A major obstacle in long-range corporate planning has been the prohibitive time and manpower requirements necessary to adequately analyze future consequences of present day decisions. An approach to the solution of this problem has been this company's development of a computerized corporate planning model. This model projects company performance for 20 years, generating for each year detailed income statements, balance sheet items, sales statistics, capitalization and key financial ratios. Management can review the projections and decide whether corporate goals have been met. If not, the model can be used to see which input parameters must be modified. Acceptable results can be translated into departmental sub-goals which meet overall company objectives. Management responsibilities of planning, coordination and control are thereby improved. Key to the model is flexibility, demonstrated by 50 variable polynomial curve fit relationships and 250 discretely-specified variables (including trend modifications). Among these input parameters are variation in product mix, sales growth rates by market category, additions and retirements of plant and capital equipment, labor expenses, interest rates and capitalization constraints. This paper describes in detail model scope and application.

WP1.14 Confidence Level in Budgeting and Forecasting, P. A. CLAVIER, *Economatics, 1188 Hillcrest Ave., Pasadena, California.*

Major improvements in budgeting and forecasting are achievable by the introduction of confidence statistics. One compares the effectiveness of three levels of sophistication: Deterministic (best guess), Most Probable Value and Confidence Level. When budgeting and forecasting, one must introduce partly known facts. Deterministically they are guessed and treated as if known. For the most probable value each one is endowed with statistics (parameters describing the statistics may also be endowed with statistics). The most probable set of results is determined. The confidence level starts with the same basic statistical description. It assesses, however, the confidence with which given results may be achieved in the future. A typical answer would be: It can be stated with such and such confidence that at such and such date, no less than such and such will have occurred. One may choose the plan which maximizes the confidence of reaching one's goal. When a number of plans and their consequences are not separable by choice, because future decisions are not predictable, and/or consequences are vague, one determines the confidence to achieve one's goal corresponding to the set of all possible circumstances. The prior choice of a confidence level shortens considerably the runtime of pertinent computer programs. Examples are given.

WP1.15 A Dynamic Programming Model for Corporate Financial Planning, WILLARD T. CARLETON, *Dartmouth College, Hanover, New Hampshire.*

In recent years considerable progress has been made in recognizing the necessary interdependency of a corporation's financial decisions: capital budgeting, borrowing or repayment, stock issue or repurchase, and dividends. Most of this progress has taken place at a conceptual level, however, and has not been translated into operational models. In the present paper, the recent conceptual advances in financial theory are incorporated into a decision-making model. The firm is

viewed as attempting to maximize, with respect to time vectors of its financial decision variables, a discounted stream of future dividends and terminal stock price (at the end of the planning horizon). The nature of the objective function and sequentially-made decisions naturally suggest a dynamic programming framework for solution. Because of accounting and economic constraints, the model can be reduced to a problem involving two state variables. Properties of the solution are examined within the context of a sample problem, and possible uses and extensions of the model are discussed.

WP1.16 The Usefulness of Sensitivity Analysis in Making Large, Long-Term Capital Investment Decisions, WILLIAM C. HOUSE, *Texas A&M University, College Station, Texas.*

Investment decisions involving large, long-term capital commitments are frequently made on the basis of whether estimated rates of return are above a certain level. Errors in estimating such underlying elements as sales prices, sales volumes, product purchase or production prices, operating expenses, capital investment outlays, and project economic life may cause estimated rates of return to be understated or overstated. Such errors can probably not be eliminated entirely. Management can determine, however, whether investment decisions based on rates of return are sensitive or insensitive to errors in the underlying elements. Such information will aid management in deciding whether to accept, to reject, or to delay acceptance of an investment proposal, pending the collection of additional information. A large gas pipeline investment proposal is examined to illustrate the usefulness of sensitivity analysis. A decision based on the discounted cash-flow rate of return was found to be very sensitive to errors in estimates of sales prices and moderately sensitive to errors in estimates of sales volume, product purchase prices, and capital investment outlays. Errors in all four estimates became much more significant when the estimated economic life was reduced from 20 years to 15 years. Errors in the other estimates examined were found to be relatively insignificant.

WP1.17 Bank Examiner Criticisms, Bank Loan Defaults, and Economic Forecasting, HSIU-KWANG WU, *Boston University, Boston, Massachusetts.*

In annual bank examinations by supervisory authorities, all bank loans above a certain cut-off point are critically evaluated by the examiners. Some of these loans, as a consequence, are formally classified or criticized as "substandard," "doubtful" or "loss." These classifications or criticisms represent expert judgments on bank loans and should be extremely useful to both the supervisory authorities and banking industry. If the classification data are highly accurate, they can also be considered as anticipation data of loan quality, which usually deteriorates during down-turns in our economy. Unfortunately, we know very little at present about the relationship between examiner classifications and subsequent loan defaults. How accurate are these criticisms? For forecasting purpose, can we use these data to anticipate changes of loan quality? This study attempts to answer these questions by examining a sample of fifty-six national banks in New England. Classified loans of the sample banks will be traced to

their ultimate disposition. Since bank examiner criticisms may reduce the probability of default, loans in actual default in the sample will also be traced back to see whether they were previously classified. Regression analysis will be used to determine the relationship between aggregate classification rates and business fluctuations. The relationship between bank profitability and the differences between classification and loss will also be examined. The data for this study are obtained from the bank examination reports and by questionnaires to the sample banks.

WP1.18 An Algorithm for the Optimal Selection, Sequence and Timing of Interrelated Major Capital Investments, WILLIAM G. LESSO, *Department of Mechanical Engineering, University of Texas, Austin.*

A model of major capital investments is developed for a firm with several existing production facilities and a number of alternatives for investment in new facilities. The model extends previous capital investment models by using discounted after tax earnings as the objective function, by determining the benefits of an alternative through optimum allocation of demand among facilities for each period and by permitting the use of retained earnings and borrowings (which are limited by past investments and earnings). The algorithm provides an optimal solution for much larger problems than could be handled with present day computer equipment using non-linear integer programming codes. A special case applicable to the extractive industries incorporating depletion allowances is given.

WP1.19 Cost Factoring System for Force Readiness Projection (COFACTS), JOE M. JACKSON, *Office Chief of Staff, Army, Force Planning Analysis, Washington, D.C.*

A major requirement in the Army is for a system to project force readiness and to relate such projections to the Army budget. If the Army is to completely close the force planning loop, it must: (a) provide the capability of translating mission-oriented statements of force structure into detailed analyses of corresponding readiness levels and budgeting requirements, (b) accept specifications of changes in readiness levels and derive the force structure and budgeting implications of such changes, and (c) translate changes in budgeting constraints into redefinitions of force structure and readiness posture. COFACTS is a systematic approach to quantitatively satisfying these vital force planning requirements. This system consists of three primary operations: (a) specification of projected forces, (b) measurement of projected force readiness, and (c) reconciliation of the Army budget with the projected forces. Appropriate analytical models and procedures have been designed and are being developed to perform each of these operations. A distinctive feature of COFACTS is the force cost model. In this approach to measuring future force readiness, the dollar cost of resources (including initiation and operating costs) serves as the common denominator by which the various facets of readiness (personnel, material, training, facilities, etc.) are reduced to a common, aggregable measure.

WP1.20 Air Force Supply of Army Field Units: A Customer's Point of View, RICHARD J. SWERSEY, *Department of Industry, University of Pennsylvania, Philadelphia.*

Most cost-effectiveness studies of air supply systems for ground units seek to optimize the utilization of the supply system. Our study, performed with the assistance of the Operations Analysis Office of TAC, is concerned with a customer-oriented measure of effectiveness—late tons. The late ton objective function was assumed to be non-linear. Its exact form depended upon the location of the supply point. For example, one ton, one day late to a battalion under attack is worth more than one ton, one day late to a division warehouse. Any modern supply system should be flexible enough to respond to varying demand patterns of field units as measured by late tons. Our attempt has been to design a supply system to serve a particular configuration of supply lines which minimizes late tons subject to a budget constraint. A Simscript model was developed and used to optimize a particular configuration and also to find an optimal configuration of supply lines. The input to the Simscript model was derived from a network flow analysis of supply.

WP1.21 Experimental Design and Simulation of Cargo Ship Unloading, ROBERT MCQUIE, *Planning Research Corporation, 1875 Connecticut Avenue, N.W., Washington, D.C.*

Should military cargo be unloaded by lighters or by helicopters? Should it be delivered through a port or directly from a ship to its destination? To evaluate these alternatives, a computer simulation was constructed of helicopters, amphibious vehicles, lighters and trucks as well as maintenance, stevedoring and supply units required to support alternative discharge systems. Cargo deliveries were simulated in both the amphibious assault and the resupply phases of a division attack. The helicopter that the model selected turned out to be sensitive to small changes in estimates of their productivities. To obtain better estimates, a series of ships were then unloaded in Viet Nam. An experiment was statistically designed to guide these exercises, similar to the designs employed in agricultural and biological field tests. Runs of the simulation provided estimates of the precision required from the experiment, and the design finally developed was a $3^1 2^4$ fractional factorial employing analysis of covariance. The principal difficulty in constructing this design was to interfere as little as possible with normal deliveries of military cargo. On carrying out the design, some factors in it will turn out to be insignificant. Those remaining will then provide the structure for a series of simulation runs to evaluate the alternative helicopter systems.

WP1.22 The Merger Decision, EAMON M. KELLY, *The Pennsylvania State University, University Park, Pennsylvania.*

Large industrial and merchandising firms are periodically involved in mergers. While the objective function of the management of merging firms is presumably common stockholder wealth maximization, little attention has been directed to optimization models for merger decisions. For this reason, this paper attempts to

develop a general decision model for the acquisition of multi-product line firms. The acquisition of a single product firm is presented initially to develop the basic concepts for the multi-product case. The essence of the model consists of relating the premium above current value to be paid by the acquiring firm to two parameter estimates of the probability distribution of incremental cash flows: the expected value and the standard deviation.

WP1.23 Prediction in a Poorly Structured Environment: Handicapping Pro Football, IRWIN GREENBERG, *School of Engineering and Science, New York University, University Heights, New York, New York.*

Every week during the last quarter of the year there appears in the press predictions of "point spreads" for professional football games. The nature of the people making these predictions—their knowledge of the game and their incentives to be accurate—as well as the apparent inapplicability of standard forecasting techniques to the problem indicates a similarity between handicapping football games and making quantitative estimates in poorly structured business situations. The performance of these football handicappers is studied and some statistical measures of their accuracy are obtained.

WP1.24 Modelling Large-Scale Educational Systems, DAVID S. STOLLER, *U. S. Office of Education, Washington, D.C., ATTN: DOA/CES/OOE.*

Several types of models which have been used to study large-scale educational systems are discussed. If one regards the educational system nationwide as a vast "servicing" operation, into which are put millions of children and out of which comes educated and trained manpower (and dropouts), one generates models of the system whose structure is based on Markov processes and network flows. Students progress through the system in a number of dimensions, only one of which is formal grade level (i.e., number of years of "servicing"). The analysis of the dynamics of measures of effectiveness of objective achievement and the consideration of the hundreds of correlatives associated with individual and group performance call for a family of models with a characteristic structure. In large scale systems, students (and teachers) not only flow through the educational system by "phases of servicing," they also flow through the system by demographic patterns. The study of these phenomena utilizes model types that are related to, but different in significant features, from the grade progression patterns. The analysis of large urban school systems produces another category of models which contains many features in common with regional development models.

WP1.25 Growth and Balanced Urbanization in America: Can Systems Analysis Help?, OLIVER BRYK, *Research Analysis Corporation, McLean, Virginia.*

If current trends continue, 300 million people may be living in a few megalopolitan areas. It cannot be taken for granted that the economic and other advantages of large concentrations of population and economic activity will be greater than their social, environmental and economic costs. The question arises whether alternatives to the current trend could be designed to create more options for the

balance between population and space, to aid in individual choice and public policy. This is a challenging opportunity for the utilization of systems skills in the public interest. RAC has begun to examine the question of growth and balanced urbanization in a small but systematic way with the objective of developing a methodology and of identifying alternatives to the present trend. Associated with these alternatives are estimates of various social and economic indicators to aid in the formulation of criteria for preference. Several models, some as yet only concepts, are being developed to assist in problem definition and analysis. The research is in an exploratory stage. A working problem definition, a preliminary system of cause-and-effect relationships, selected alternatives and associated measures will be presented for professional comment.

WP1.26 A Computer System for Projecting Budget and Manpower Requirements of a Project-Oriented Organization, EARL M. WARD, *Westinghouse Astronuclear Laboratory, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania.*

The Project Monitoring and Manpower Projection System, "PM & MP," offers a method of projecting manpower needs of various types of personnel based on existing contracts and on probabilities of obtaining certain future contracts and their associated manpower demands. It projects the entire range of probabilities from 0 to 1 and the manpower requirements associated with each. Then certain probabilities are selected for plotting over time so that management can make informed decisions on hiring policy in advance of actual requirements. In the same manner cost estimates are collected and projected. An associated critical path program, scheduling and monitoring all contracts, can anticipate manpower shortages and suggest inter-project transfers.

WP1.27 Managing and Motivating Computer Systems People, FRANK GREENWOOD, *Ohio University, Athens, Ohio.*

Alfred P. Sloan wrote: "The importance of research work as contributing to the advancement of industry through scientific study is well established. The marvelous contribution that it has made to the progress of industry and the advancement of the standard of living, is universally accepted. It is not so generally recognized, however, that research may be equally well applied—and it is important that it should be applied—to all functional activities to a business." Systems analysis can be defined as the application of research to the functional activities of a business. A data processing executive with a billion dollar manufacturing corporation corroborated this in stating: "The problems of control and the mission of data processing are analogous to those of research and development, . . . Data processing may be as important to the future of business as product research and development." Assuming that computer systems analysis is indeed the application of R&D to the functional activities of a business, then it should be fruitful for students of the R&D process to inquire how to manage and motivate computer systems analysts. This paper considers this, including the areas of: management and motivation, leadership and motivation, self-fulfillment and motivation, and organizational considerations.

WP1.28 Decision Criteria for the Funding of Higher Education, FRED BETZ, CARLOS KRUYTBOSCH and DAVID H. STIMSON, *Space Sciences Laboratory, University of California at Berkeley.*

The paper deals with the financing of higher education and depicts the gross features in the decision structure of the system which encompasses the state university and its major funding sources, the state government and the federal government. The analysis focuses on the communications network between the university and its funding sources, and the manner in which the communications have helped develop the images which the funding sources hold of the university. The impact these images have on the decisions made by the funding sources is explored. Some current administrative problems of the university are a result of the state government and the federal government holding different images of the university. A discussion of these problems and some suggestions for their solution concludes the paper.

WP1.29 Three Fundamental Laws of Systems, RICHARD M. GREENE, JR. *International Center for Executive Development, 211 West Foothill Blvd., Glendora, California.*

There are no single causes or effects in systems—the absolute rate of change of a system is a function of its current structure and environment, and to observe a system means to change it. These system laws are violated daily in business and operations analysis. Examples will be drawn from several types of systems—missiles, people, corporations—to show how these laws work and what can be done when an analyst is aware of them.

WP1.30 Gaming the Large Public Accounting Firm, RICHARD F. BARTON, *Texas Technological College, Lubbock, Texas.*

The task of developing a noncomputer training game to reflect both the separate functions and a firm-as-a-whole view of a large public accounting firm presented problems of game model design and of physical execution. The purposes of the game project were: 1) to provide an orientation to the firm for new employees, 2) to offer an opportunity to exercise management skills for experienced members of the firm, 3) to stimulate reflective insights into the leadership functions of the firm, and 4) to be fun and a feature of the firm's hospitality to clients and prospective employees. Visits to different types of offices of the firm were made by the game writer. The player role finally chosen for the game was that of a single hypothetical general manager of one office of the firm. In this position, the player must concern himself with scheduling, staffing, and organizing the three major client services of his office, which are auditing, tax services, and management services. The simulated office managed by the player exists in an environment that contains prospective clients, potential employees, up to three competing offices, and uncertain events that affect each firm's present list of clients and present staff. General development units are earned by a player through uncertain events. The final score for a play of the game is the total net billable time plus the accumulated general development units. Over one hundred participants played the game during a single training conference.

WP1.31 Some New Statistics For Evaluating and Predicting the Support Performance of Complex Multi-Echelon Logistics Systems, PAUL BROCK and BRIAN GLUSS, *General Electric: TEMPO, Santa Barbara, California.*

Consider a complex multi-echelon logistics system whose stochastic inputs comprise supply of money and materiel at the upper ("logistic") echelons and use of materiel at the lower ("operational") echelons. Usage at the lower echelons corresponds, for example, to replacement of failed and used parts. When logistics systems are very simple and well behaved, it is sometimes possible to determine the required flow characteristics of the system analytically. As the systems considered become more complicated, closed mathematical solutions quickly become impossible and simulation is used: demands are generated and their effect is traced back and forth through the system, taking into account budgetary assets, the times at which stock reaches the various echelons, and the inventory of stock at the various echelons. A further stage of complexity exists, however, at which the system is so complicated and large that simulation of the entire system requires prohibitive computer storage space and running time. For this type of process, in order to make the quantity of information manageable in the simulation, it is therefore necessary to be selective concerning what information we choose to observe and use for making inferences on the performance of the system. Note, also, that as the system becomes more complex, the lower and upper echelons tend to have completely divorced objectives: the former to function effectively, and the latter to provide effective logistic support. A partitioning of the system into two parts, the lower and upper echelons, is thus a very natural one, and the statistics discussed in the paper involve such a partitioning. These statistics are of use in evaluating and predicting the support performance logistically, in addition to their effect on system operation or readiness.

WP2 *Panel On: Trends in the Theory of Vehicular Traffic Flow and Control, CHAIRMAN: DENOS C. GAZIS, *IBM Research Center, Yorktown Heights, New York 10598.*

A review and appraisal will be given of work in the following five major areas: 1) *Traffic Flow on Roads* (R. W. Rothery), including both single lane and multilane facilities, but without regard to intersections, merging and control. Both the microscopic and macroscopic descriptions of traffic will be discussed. 2) *Stochastic Models of Traffic* (A. V. Gafarian), including models of multilane unidirectional flow, crossing and merging problems, queueing and parking. Particular emphasis will be given to studies of multi-lane, unidirectional highway characteristics. 3) *Traffic Distribution Models* (R. M. Oliver), including gravity models, proportional flow models and recent work by Murchland at the London School of Economics and Loubal in the Bay Area Transportation Study. A comparison of the traffic flows predicted by these models will be made for a nine-zone example selected from the San Francisco Bay Region. 4) *Models for Estimating Demand for Intercity Passenger Transportation by Mode* (A. J. Goldman). This will be a review of both theoretical and empirical aspects of such models developed by several organizations. 5) *Traffic Control* (D. C. Gazis), including a discussion of work on the synchronization of traffic signals for a city street network and al-

gorithms for the control of traffic by an on-line computer. Short presentations on the above five topics will be followed by a panel discussion, with maximum encouragement of audience participation.

WP3 *Panel on: New Concepts in Organizational Design, CHAIRMAN: KENNETH E. KNIGHT, *Stanford University, Palo Alto, California 94305.*

Traditional forms of organization are being challenged by a growing dissatisfaction with their performance in a rapidly changing world. This dissatisfaction is based, in part, on the dissemination of research results illustrating typical dysfunctions. It is also based on the increasing visibility of alternative design ideas not being exploited. Prominent among the sources of new design ideas are analogies with architecture, biological organisms and computers. Important current questions are: 1) It is possible to integrate the notion of "dysfunction"—its generating processes—with the assumptions that are implicit in the analogies just mentioned; assumptions of conscious planning, coherence with human and social purposes, richly interdependent system, and functionally complete decision process? 2) What features of organization structure are susceptible of manipulation for design purposes? 3) What techniques are available for manipulation of organization structure.

WP4.1 * Recursive Approximation to Optimum Rules in Statistical Decision Processes, GEORGE W. BROWN, *University of California, Irvine, California.*

Many dynamic decision problems may be modeled in terms of a Markov process with underlying state not directly observable. The particular model examined postulates, at integer times t, an unknown state s_t, a chosen action α_t, and an observable x_t, such that x_t and the next state s_{t+1} have known joint probability distribution for each combination of s_t and α_t. Overall cost of the process is taken as the total of discounted current costs over time, with the current cost a function of the current state and action. A number of different decision problems may be represented, including various generalizations of sequential experimentation, inventory problems with underlying demand parameters unknown and subject to transitions, problems of inspection, repair and replacement, and dynamic budgeting processes. Recursive sets of rules are defined in terms of initial acts and a mapping of the observable onto the set of rules, corresponding to appropriate selection of a new rule next time. A class of algorithms for approximating optimal solutions is defined by construction of sequences of recursive sets of rules. Given initial state probabilities, iterated application of an approximating recursive set of rules generates an expected cost no greater than that of the best rule of the set.

WP4.2 * Extensions of LaGrange Multipliers in Nonlinear Programming, F. J. GOULD, *University of Chicago, Chicago, Illinois.*

This paper presents results on the theory of Lagrange multipliers in nonlinear programming. Kuhn and Tucker give relations between the saddle points of a Lagrangian function and the solutions to a nonlinear program when certain differentiability and regularity assumptions are made. Everett and others drop the

differentiability assumptions and seek to solve the nonlinear programming problem by finding an extremum for a constrained Lagrangian. It is recognized that this procedure yields a solution to the programming problem only in certain cases. This paper defines a generalized Lagrangian problem which has a solution whenever the nonlinear programming problem has one. It also suggests a computational procedure and indicates certain areas of application.

WP4.3 * Faces of an Integer Polyhedron for Groups of Prime Order, FRED GLOVER, *Department of General Business, College of Business Administration, The University of Texas at Austin, Austin, Texas 78712.*

Particularly strong cuts for integer programming are given by faces of certain "integer polyhedra," as pointed out by Ralph Gomory in the third of his pioneering papers on solving integer programs by reference to group theoretic relationships. Of key significance is the problem of generating faces of polyhedra for groups of prime order. However, no efficient method for generating more than $(p+1)/2$ such faces, where p is the group order, is known. This paper develops new group theoretic results that provide three methods for generating large numbers of faces very rapidly.

WP4.4 * A New Approach to Combinatorial Programming, GLENN W. GRAVES, *University of California, Los Angeles, California.*

Combinatorial programming problems almost by definition involve natural classes of finite maps which specify the possible alternatives. By using these classes of maps directly, one can avoid the artificial introduction of large numbers of variables and structural constraints. This paper employs a compact constructive procedure for efficiently generating all maps in a finite class of maps, and gives a methodology for using the inherent flexibility of this procedure in order to quickly determine very good maps for a wide range of problems. This methodology sequentially fixes elements of the map on the basis of the future cost implications at each stage. Combinatorial probability techniques are used to obtain useful global information concerning the ultimate value of the completions of a partial map. Implicit enumeration using this approach, in conjunction with "truncation tests," yields an optimal map. The approach advocated here also opens the way to a relaxation of a complete implicit enumeration to a "confidence level" implicit enumeration for finding good maps (with confidence bounds). Computational experience with large problems is described which shows that nearly optimal maps are usually found quickly.

WP4.5 * Location-Allocation Problems: A Survey, WILLIAM W. HARDGRAVE, *Bell Telephone Laboratories, Inc., Holmdel, New Jersey 07733.*

The location-allocation problem is to determine the optimal number and locations of central distribution facilities (e.g., warehouses, telephone central offices) and to allocate the demand points to the centers. This review paper surveys and evaluates the existing literature on the theory and computation of this problem, and partially unifies this literature through a compact classification scheme based on the four major components of location-allocation problems: the set of demand

points; the admissible locations for centers; the cost of serving a demand point from a center at a given location; and the cost of establishing a center. This classification procedure not only yields a general statement of the problem in its various forms, but also allows us to distinguish it from closely related problems such as the Steiner and facility location problems. The natural formulation of the location-allocation problem is a minimizing nonlinear program, generally with a non-convex minimand. The surprisingly few serious mathematical results that are available can generally be interpreted as special cases of results in nonlinear programming. However, the existing literature (with a few notable exceptions) consists largely of proposals for approximate algorithms for a few special cases. A number of aspects of the location-allocation problem which are deserving of serious mathematical study are described.

WP4.6 * Conjugate Convex Functions and the Decomposition Principle, R. T. ROCKAFELLAR, *University of Washington, Department of Mathematics, Seattle, Washington.*

For $i = 1, \cdots, m$, let C_i be a convex subset of R^{n_i}, and let f_i be a convex function on C_i. Let (P) be the problem of minimizing

$$f_1(x_1) + \cdots + f_m(x_m)$$

subject to the constraints

$$x_i \in C_i, \qquad i = 1, \cdots, m,$$

$$A_1x_1 + \cdots + A_mx_m = b,$$

where $b \in R^n$ and A_i is an $n \times n_i$ matrix for $i = 1, \cdots, m$. It may be proved that, under a simple hypothesis, there exist vectors $z_i \in R^n$ such that the optimal solutions $(x_1, \cdots, x_m)$ to (P) can be determined by solving m independent problems: minimize $f_i(x_i) - z_i^T A_i x_i$ subject to $x_i \in C_i$. The vectors z_i may be determined in principle by solving a certain dual problem involving the conjugates of the functions f_i.

WP4.7 * Cutting Plane Algorithms as Mappings on a Space of Sets, W. I. ZANGWILL, *University of California, Berkeley.*

Cutting plane algorithms such as the Kelley method, the Veinott Supporting Hyperplane method, and the dual of the Dantzig-Wolfe Decomposition method may be viewed as different forms of a mapping. This map operates on sets to yield new sets. By showing this map is continuous, convergence of these algorithms immediately follows via application of this author's Theory of Convergence. The mapping concept reveals that cutting plane methods are intimately related to other forms of algorithms.

WP5.1 A Heuristic Simulation Approach for Locating Warehouses and Plant Facilities, DANIEL W. SIFFERD and BHAMY V. SHENOY, *Continental Oil Company, Ponca City, Oklahoma.*

This paper outlines a heuristic simulation approach to location of warehouses and production facilities, giving a brief outline of the computer program used in

an actual case. In most cases sales of commodities, such as gasoline and fertilizers, are inversely proportional to the distance from the warehouse. Given the potential demands at potential warehouse locations, simulation is done to find the possible sales for various sales vectors. This initial run gives an idea of possible warehouse locations. Then further runs are made on a mutually exclusive basis to find the number of warehouses to match the plant capacity, or, given the number of warehouses, to find the plant capacity. It is also possible to get total cost of transportation and distribution for different sets of warehouses by incorporating cost figures in the computer program.

WP5.2 Location and Production: An Algorithm, R. A. MAGGIO and J. L. DAKE, *Georgia Institute of Technology, Atlanta, Georgia.*

A decision-maker must determine minimum cost plant location as a function of cost of raw material inputs, and non-linear transportation rates for both raw materials and finished product. This paper develops a procedure for such minimization based upon the Box-Wilson or response surface design. Under this procedure, an experimental search using paths of steepest ascent is conducted for an extremum of a response surface when its functional form is unknown. The surface in the present situation is generated by the independent variables 1) raw material costs, and associated transportation costs, and 2) finished product transportation cost; the dependent variable is total cost As a means of illustration, a model for a product consisting of two raw materials and one market is presented. The paper concludes with comments relative to extension of the procedure to an n-dimensional surface consisting of several input sources and markets, and possible modification to reflect selling price.

WP5.3 A Model for "Optimizing" Distribution Systems, DAVID L. ELDREDGE, *Mead Johnson & Company, Evansville, Indiana.*

The problem addressed is that of determining an efficient (i.e., low cost) and effective (i.e., high service level) system for distributing consumer products. The elements of the distribution system include manufacturing plants, warehouses, demand point, and transportation routes. Thus, the solution to the problem must answer questions such as: (1) where should the manufacturing plants and warehouses be located, (2) what modes of transportation should be used, and (3) how frequently should shipments be made? To answer such questions, the Mead Johnson Model for "Optimizing" Distribution Systems called MODS, was developed. This model determines the least costly distribution system under a set of conditions which include the possibility of (1) more than one product type, (2) mixed product shipments, (3) transportation and transshipment rates dependent upon the quantity shipped, (4) fixed costs, and (5) customer service level restrictions. The model has been programmed on a digital computer to treat distribution systems with up to 10 potential manufacturing points, 40 potential warehouse points, 225 demand points, and 8 product types.

WP5.4 An Algorithm for Solving the Multifacility Production-Transportation Problem With Nonlinear Production Costs, J. FRANK SHARP, *School of Business, New York University,* JAMES C. SNYDER and JAMES H. GREENE, *Purdue University, West Lafayette, Indiana.*

In the model considered in this paper, a firm with several plants must supply several markets with known demands. Production costs are nonlinear while transportation costs between any plant-market pair are linear. The firm desires to minimize total production and transportation costs. The Kuhn-Tucker conditions and the dual to the transportation model are used to derive optimal conditions for this problem. These conditions are shown to be both necessary and sufficient if the production costs are convex at each plant, and are necessary otherwise. An algorithm is developed for reaching an optimal solution to the production-transportation problem for the convex case.

WP5.5 Plant Location Under Economies of Scale In Production and Transportation, DAVID RUTENBERG, *Carnegie-Mellon University, Pittsburgh, Pennsylvania.*

An exact solution technique is presented to find the optimal capacity of single product plants which can be constructed in n possible sites whose costs of construction and operation display economies of scale. The total capacity of the plants must satisfy the known demands of m markets, and there are also economies of scale in transportation from each plant site to each market. Theorems on the constrained minimization of concave functions by Mangasarian and of Zangwill lead one to enumerate and evaluate n^m possible plant-market allocations. In this paper the bulk of these possibilities are culled from consideration by recasting the problem as a two stage dynamic program, in which the second stage is merely the search for degenerate solutions to an allocation problem. Yet a further reduction can be made in the number of points to evaluate. The envelope of total production cost is concave. The envelope of optimized transportation costs is linearly piecewise convex. Hence a global minima could occur in only two regions on the sum of these cost functions, so not all the degenerate solutions to the allocation problem need be found. The branch and bound algorithm of Efroymson and Roy (*Operations Research,* May–June, 1966) is probably quicker if the concave costs can be approximated by a fixed cost plus a linear variable cost. This approach taken in this paper, however, directly handles smooth continuous concave functions.

WP5.6 Multi-Centers and Multi-Medians of a Graph with an Application to Optimal Warehouse Location, SIDNEY SINGER, *Dunlap and Associates, Inc., Darien, Connecticut.*

Computational algorithms are developed for determining multi-centers and multi-medians of a weighted graph, that is, one with weights associated with each node, as well as with each branch. The p-center of a weighted graph G is the set of p points in G for which the maximum weighted distance to any node in G is a minimum. The p-median of G is the set of p-points in G for which the sum of the weighted distances to every node in G is a minimum. Numerical examples are

presented to illustrate the procedure for $p = 1, 2, 3$. The application of the p-median to the problem of optimal warehouse location in a distribution network is also considered.

WP5.7 Historical Estimating Behavior and Network Simulations, WILLIAM R. KING, *University of Pittsburgh, Pittsburgh, Pennsylvania.*

Historical time estimating behavior is considered as a valid basis for the planning and control of projects using network techniques. The empirical evidence underlying this assumption is reviewed and a simulation approach to network analysis using historical time estimates as input data is described. The approach provides an operational device for management planning and control which obviates many of the theoretical and behavioral difficulties encountered with network techniques.

WP5.8 DCPM: Network Reduction and Solution, WALLACE B. CROWSTON, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

The DCPM problem may be termed a discrete time-cost tradeoff problem generalized to include the possibility of interdependency constraints between the discrete job alternatives. It has been formulated as an integer programming problem and solved by integer programming and by heuristic techniques. This paper shows that a variant of the usual critical path method may be used to reduce the DCPM network to an equivalent network containing only decision nodes and maximal distances between them. This operation, along with feasibility tests on the interdependency constraints, allows substantial elimination of the precedence constraints in the programming formulation. A branch-and-bound method is then developed to solve the reduced problem. Computational results with various branching strategies are given.

WP5.9 Simulation of a Liquid Container Distribution System, ERNEST FREUDMAN, *General American Transportation Corporation Niles, Illinois.*

Central to the system configuration is the distribution terminal. Here liquid commodity arrives by tank car and is transferred to smaller containers. Trucks arrive with an empty container, are loaded, and then leave for the dealer. A dealer places a call for a container when his present container is empty. The terminal itself provides no permanent storage and the commodity in question is highly seasonal. It was required to find the relationship between: 1) scheduling of tank cars, 2) number of containers per dealer, 3) number of trucks, 4) expected waiting time of a dealer for a container. Given the cost of losing a dealer's order, the terminal operator faces the problem of minimizing total costs. An interesting aspect of the study is the cost of simulating the distribution system in relation to the degree of solution. Three problems are considered; the number of observations for each combination of factors, the number of factors to be considered, and the optimization. It is assumed something is known about the factors and their interrelationship; a part of this knowledge is built into the model. After a number of runs of the model, this knowledge is implemented and used to further direct the shape of the model and the optimization process.

WP5.10 Simulation in Power and Free Conveyor Systems, KENNETH R. EATON, JR., *University of Michigan, Dearborn, Michigan.*

The purpose of this paper is two-fold. First, it demonstrates the use of the Kolmogorov-Smirnov statistic to validate a simulation against known analytic results and the concepts of design of experiments in preparing computer runs for the study of unsolved problems. Secondly, it shows that simulation can give generalizable results to problems which are not analytically tractable. Palm's solution to the overflow problem is well known to those involved in the study of queuing processes. Unfortunately, Palm's solution does not allow for storage before the service stations and, because of the inversion of the Laplace transform, it is extremely difficult to solve in closed form for $N > 3$ stations. However, this problem appears quite often in power and free conveyor systems where storage is present in "free" lines before the service stations. Since Palm's solution is sufficiently complicated with zero storage, a simulation appears to be a legitimate technique for studying the problem. A simulation is designed to 1) Obtain the parameters for Palm's solution for $n = 1, 2, \cdots, 10$ stations and 2) Obtain the form and parameters of the solution when storage is present in the systems for $n = 1, 2, \cdots, 10$ stations and $S_i = 1, 2, \cdots, 10$ stored items at each station.

WP5.11 Value of Time Share Terminal For Simulation Work, With Examples, DONALD H. MAUND, *Operations Research Department, American Airlines, Inc., 633 Third Avenue, New York, New York.*

The Time Share Terminal offers some unique advantages for simulation problems. Primarily, these are ease and speed of programming and debugging, rapid and creative modification of logic and print-out, "sales effectiveness" of results, especially with hands-on demonstrations to management. This paper discusses some recent work using a Time Share Terminal for simulating multi-server, multi-period queueing problems. A generalized model was written to overcome difficulties of realistic transitional analysis of peak periods bracketed by various build-up and drop-off activity rates. Specific examples discussed are an Air Freight Terminal Truck dock, and congestion on aircraft taxiways at a major airport.

WP6.1 Predicting Traffic Loads in the Transportation Network North Rhine-Westphalia, MARTIN J. BECKMANN, *Brown University, Providence, Rhode Island.*

In order to forecast traffic flow for 1980, the response of traffic demand to basic socio-economic variables such as population, per capita income, trip purpose, and automobile ownership is estimated in the framework of a general gravity model. Modal split between rail and road requires an analysis of the effects on modal choice of time and money cost differences and of automobile ownership. Next the growth of automobile ownership is predicted regionally. Finally, the interaction of demands with existing and anticipated capacities leads to a traffic assignment which represents the forecast in the case of no changes in the network. But the method is adaptable to estimating the impact of various investment and policy actions. The data situation is unusually favorable, based on a complete traffic count by modes and trip purpose of traffic between 125 cells, of income and

automobile data for these cells, and of time and cost data for travel by road and railroad between all pairs of cells. The geographic scope of this forecasting model goes far beyond the usual traffic models for metropolitan areas.

WP6.2 Simulation of a Maritime Shipping System, MURRAY L. WANGER, *U. S. Maritime Administration, Washington, D.C.*, SHARON ROSE and ARNOLD L. WEBER, *National Bureau of Standards, Washington, D.C.*

This critical event-oriented simulation represents the operation of a commercial shipping fleet. A critical event occurs when a ship enters a port. There, cargo is discharged, and cargo destined for other ports (break bulk, containerized, and liquid commodities generated by user-specified functions of deterministic or random variables) is taken on as space permits. Input data concern trade routes and ship designs. A ship's itinerary is limited neither as to number of ports visited, nor sequence of visits, in that ports may be revisited within the span of one voyage. At the user's option, "feeder" networks bring cargo to specified ports for transshipment to ports in adjoining networks. Ship configurations can be specified precisely with respect to individual holds. Labor practices and power plants are also depicted. The model has been programmed in FORTRAN for the H200, H1200, IBM 360/40, and UNIVAC 1108 computers. The program imposes no restrictions on the number of days simulated. Outputs include ships' manifests, and data on times and costs of loading and unloading, overstowage, load factors, and container inventory fluctuations at ports. Illustration of the simulation's use in evaluating some alternative routines, schedules, and ship design configurations is given.

WP6.3 Socio-Economic Evaluation of Urban Transportation Systems, MARTIN J. BECKMANN, *Brown Univ., Providence, Rhode Island,* JAMES P. WALLACE, *General Motors Research Labs, Warren, Michigan,* and RALPH L. MILLER, *General Motors Building, Detroit, Michigan.*

This paper presents a systems approach to satisfying the transportation-related needs of an urban area. The process begins with a deficiency analysis of the existing transportation system in the light of both current and forecast transportation-related demands. These demands include the requirements for moving both people and freight, as well as such social, economic and political requirements as reducing air pollution, improving aesthetics, and providing a system consistent with desired land use patterns. The second step is the design of alternative transportation systems proposals to meet these requirements. Since no system can fully meet every desirable objective, an evaluation step is needed which highlights the basic trade-offs that must be made. Extensive analytic tools have been developed to measure both user and non-user benefits and costs, as well as the overall economic feasibility of the system. In addition to providing an integrated interdisciplinary methodology, the paper also presents advances in certain specific submodels such as new mode demand estimation and economic feasibility models.

WP6.4 Scheduling in a Transportation Network, ROY MACDONALD-TAYLOR, *Bell Telephone Laboratories, Inc., Murray Hill, New Jersey.*

The problem deals with scheduling vehicles in an intercity passenger transportation system. A particular example system is used to test the feasibility of the method developed. The city pair demand varies in two ways, the first for different time periods during the day and the second a day-to-day variance for a given time period. The research steps are: 1) develop criteria to measure the effectiveness of a schedule, 2) develop heuristic decision rules for scheduling, 3) establish schedules using these rules, 4) evaluate them in terms of the criteria, 5) develop and apply rules to modify schedules and evaluate the modification, 6) make conclusions. The basic research tool is simulation using the computer. The values of the method are seen as their flexibility and the extensive evaluation of scheduling procedures that can be achieved for quite minimal computer time. The results do not indicate any one decision rule to be uniformly the best for all criteria. However, some general conclusions and some conclusions specific to the example system studied are made.

WP6.5 Computer Aided Approach Spacing for Terminal Air Traffic Control, W. H. KOCH, *National Aviation Facilities Experimental Center, Atlantic City, New Jersey.*

The results of laboratory and field tests of an experimental computer system which provided aircraft rate control and spacing assistance in terminal area approach control are described. A general purpose digital computer was used to provide aircraft heading, speed and turn information, in symbolic and numeric form, on a radar display used by the final approach controller. This information was used by the controller in maintaining minimum spacing between succeeding aircraft consistent with safe operation. Additionally, an input/output device at the flight data location indicated which aircraft should depart which outer fix at a given time, in order to establish and maintain a consistent "first come—first served" traffic flow in the final spacing area. Initial testing was conducted at the National Aviation Facilities Experimental Center, located in Atlantic City, New Jersey, using simulated and live aircraft. The system was subsequently relocated to the J. F. Kennedy Terminal Radar Control facility at New York City for further evaluation. Test results of the final spacing function indicated that more accurate and consistent landing intervals, and a proportionate increase in arrival rates, were obtained with the use of the computer system when compared with the manual system. Acceptance of the system by the operating controllers was limited due to an increase in work load on the controllers caused by system input and update requirements.

WP6.6 Air Freight Transport and the Problem of Peak Demand, IRVING J. CASEY, *Analytic Services Inc., Falls Church, Virginia.*

The only inherent advantage of air transport over other transport modes is speed. If the air freight industry is to maintain its advantage as traffic increases, it must be capable of satisfying maximum demand for air shipment on any day. Failure to meet peak demands in this manner will result in diversion of freight by

the consignor to other modes of transport. The excess capacity required to meet peak demands will become a major problem as the general demand for air freight transport increases. The amortization alone, on aircraft now being built (e.g., the Boeing 747), will be in excess of $400 per hour—whether the aircraft is in use or in reserve. Because of the high cost, it is apparent that cargo aircraft cannot be kept in reserve on the ground to meet peak demands. Solutions other than maintaining aircraft in reserve will require changes in the present practices of air freight carriers. Some solutions examined are: consignment of air freight to airports and air carriers on a regional, rather than local airport basis, with the establishment of off-airport terminals to accomplish this consignment; establishment of routine intercarrier transfer of freight before air carriage; and authorization for regional operation by air freight forwarders.

WP6.7 Airline Operations and Planning Model, JOE D. KINGSLEY, *Douglas Aircraft Company, Long Beach, California.*

The Airline Operations and Planning Model is a set of computerized programs designed to help in fleet planning for the various airlines of the world. These programs will cover all the operational aspects of an airline which determine the size and composition of an airline fleet. This project has been designed to be a five-year project, and to date we have eight operating programs most of which are at the state of the art in their particular area. For example, The Schedule Planning and Evaluation Model schedules flights, develops itineraries, and allocates future demand by time of day and day of week. Another program which the McDonnell Douglas Corporation has developed is the Douglas Route Analysis. This program simulates the operation of an aircraft from block to block. It is recognized that these programs could go into great detail and complexity. In fact, it is possible to go into a level of detail such that the programs may never be completed. The aim is to include those details which significantly add to the answer. For example, there are programs operating today that go into the scheduling and allocation of individual passengers and cargo throughout the entire system. These programs have been studied for their contribution to the overall operation of an airline, providing analysis in areas that have been determined to be strong in control of finances, growth, revenue, and total operating capacity of an airline has been looked at for their sensitivity in contributing to the total corporate objectives.

WP6.8 Airline Fleet Planning—Restricted Models, MEHMET GUREL and LOUIS VARGHA, *The Boeing Company, Commercial Airplane Division, Renton, Washington.*

Many attempts have been made and will continue to be made to build a general airline fleet planning model. Most of these attempts are characterized by an intention to achieve complete generality to forecast the best fleet composition. Some of these models are in closed mathematical forms. By applying optimization techniques, optimum solutions to these models are obtained. However, contrary to intention, these models cannot be used to determine the number of aircraft (by size and type) in a given airline system Furthermore, although use of such models may provide useful information concerning the system under con-

sideration, it generally leads to additional questions as well. Since interpretation of the results obtained from these models is not clear, and since their use is time consuming (both computer use and input preparation) they are not generally used for airline fleet planning forecasting. In this paper brief evaluations of this class of models are presented; special forms which give rise to more simple computations are noted; the deficiencies and their reasons are investigated and depicted. In conclusion alternative approaches which merit the consideration of any planner who becomes involved in forecasting fleet composition are presented

WP6.9 Time of Departure Assignment in Aircraft Scheduling, BRADLEY J. HEAP, *Douglas Aircraft Company, Long Beach, California.*

One of the most pressing problems facing an airline management today is that of scheduling an aircraft fleet in a system of competitive markets. In order to effectively service the demand for air travel existent in an airline system, management must co-ordinate various operating considerations, among which are: 1) size and type of fleet, 2) Civil Aeronautics Board granted route authority, 3) the number and size of major markets, 4) the travel preferences of those persons making up each of the markets in the system. Topic four is expanded in the paper. Explanations are given for observed demand behavior, and most importantly, a methodology is presented which will allow scheduling managers to assign optimum departure times to new flight frequencies. This methodology is being developed by the author at the aircraft division of the McDonnell Douglas Corporation as part of an airline schedule planning and evaluation simulation model.

WP6.10 Probability: An Application to Projected Airline Cash Flow, PAUL T. GLASGALL, *Douglas Aircraft Company, Long Beach, California.*

The development of a probabilistic model for projecting the future cash flow of an airline makes available a powerful sales and planning tool for aircraft manufacturers and the airlines. The model will make available, to those concerned, projections of an airline's future fleet capacity requirements and purchasing ability. These requirements are dependent on future demand projections which form the basis for selection of a fleet mix through analysis of the generated revenues and costs. The funds required to keep the airline in a financially strong position are also considered. Inputs, trends and results are projected and determined through the use of various mathematical and programming methodologies. Statistical and probabilistic methods are then incorporated to analyze the results and give managers some indication of the sensitivity, probability and importance of the various inputs and results.

WP6.11 Econometric Passenger Demand Forecasting Model, RONALD J. SCHMIDT, *Douglas Aircraft Company, Long Beach, California.*

The Econometric Forecasting Model is comprised of a multiple regression which is applicable in forecasting revenue passenger demand by city pairs for local and domestic trunk operations. The multiple regression provides a method of simultaneously analyzing the functional association among the employed variables that are compiled within the model. These variables include: 1) fare elasticity, 2)

disposable income, 3) sales activity, 4) population, 5) quality of service, and 6) intercity distance. Inclusive within the model is a market share forecasting probability function of 1) market density, 2) competitive carrier's philosophy, 3) growth of the market, 4) equipment type and availability, 5) number of segment stops and 6) Civil Aeronautics' Route Restrictions. The forecasting model was developed under the criteria that: 1) the model should incorporate the most pertinent statistics that are available and/or can be derived by city pairs, 2) the model should compensate for the inadequacies of a strict extrapolation of historical traffic by city pairs, 3) the basic assumptions and mathematical methodologies should be kept to a reasonable minimum in order that revenue passenger demand forecasts will be meaningful and logical, and 4) the model should be constructed with built-in flexibility in order to facilitate the absorption of shifting relationships.

WE1.1 *Construction of Student Fees at the University of California, BURTON WOLFMAN, *Office of Analytical Studies, University of California, Berkeley.*

In January 1967, the newly-inaugurated Governor of California proposed the establishment of a $200 University tuition for California resident students as one of the solutions to the State's fiscal crisis. The author will review the sixteen-month (May 1968) history of the University's "Tuition Crisis" and describe the administrative and political decision-making apparatus involved. Of more immediate interest to the reader, the author will explain the variety of analytical questions raised by the tuition issue and describe, in detail, the results of the research effort undertaken by the Office of Analytical Studies to provide answers. Some of the critical analytical questions which were raised were: What impact would price increases in education have on the total demand for education; what impact would price increases have on particular segments of demand, especially low-income and disadvantaged students; how can fee increases be used to alter the composition of student enrollment to make the University equally accessible to all groups; should financial aid be offered on the basis of "need" as determined by an arbitrary formula or should financial aid be administered in accord with a willingness-to-pay concept which would imply that the first priority demand on a financial aid program would be to bring students to the University who are presently already priced out of the market as opposed to aiding students who are currently enrolled. Some of the research that has been carried out by the Office of Analytical Studies included a survey of the socio-economic characteristics of high school seniors, determination of the socio-economic characteristics of the students enrolled in the University of California and their financial resources, assessments of the adequacy of existing financial aid programs and costing-out of alternative financial aid programs.

WE1.2 *Student Enrollment Predictions, SIDNEY SUSLOW, *Office of Institutional Research, University of California, Berkeley.*

The author will discuss the problems of prediction of student enrollment as they relate to both short and long range University planning. The discussion will include the effects of transfers, accelerations, student demand for admissions, withdrawals, dismissals, and enrollment quotas.

WE1.3 *A Model of Faculty Appointments and Promotions, ROBERT M. OLIVER and ROBERT GOOBY, *College of Engineering, University of California, Berkeley.*

The authors discuss a model of faculty appointment, promotion, resignation and retirement in which there are fixed costs in change of status, quota restrictions on total and non-tenure faculty and minimum levels on the expected rate of tenure appointments.

WE1.4 *On a Class of Quota Restricted Admission Policies, RAMASWAY CHANDRASEKARAN, *Optimum Systems, Incorporated, 2600 Camino Real, Palo Alto, California.*

In this paper, we are concerned with various policies for admission of students to a University. We assume that the arrival of applicants follows a poisson process and that the value of an applicant is a random variable with a known probability distribution. Given a time period T within which we can admit at most N students, we wish to maximize the total expected value of all students admitted. We first consider policies where admission or rejection of a student is decided at the instant, t, that his application is received and then consider policies where the decision to accept or reject is made at a time τ between receipt of his application and the end of the planning period.

WE2 Workshop: Marketing Information Systems, CHAIRMAN: DONALD F. COX, *Coca Cola Company, P. O. Drawer 1734, Atlanta, Georgia 30301.*

Problems of design and diagnosis of information systems in marketing will be discussed. For purpose of the discussion, marketing information systems are defined as sets of data—possibly computerized—concerning sales, costs and the external market information available to the firm, with a retrieval and display system designed to make the data readily available to marketing decision makers. Formal papers may be presented as part of the workshop.

TA1.1 Goal Setting Practices in American Industry: An Empirical Study to Assess State-of-the-Art, C. R. KLASSON, *University of Iowa, Iowa City, Iowa.*

The paper reports on a study of "goal setting practices" in 168 major U.S. corporations (banking, insurance, utilities, transportation, and manufacturing) as of August, 1967. Study was conducted: (1) to assess the present state-of-the-art in view of related behavioral findings in the area of participated management, (2) to identify some of the major problems connected with implementing formalized "management by objective" philosophies, and (3) to identify some researchable problems associated with corporate planning and control processes. Descriptive statistics were gathered from survey questionnaires completed by senior corporate line and staff managers. Field interviews were held with corporate officers and staff specialists in fourteen companies. Data was also collected from personnel research staff currently examining various aspects of "standard programs" as related to managerial development and utilization. Data is first the broad account regarding actual

practices in this area and serves to point up some of the major obstacles associated with building viable "change programs" to bridge the gap between current normative theory and actual practice.

TA1.2 The Optimal Planning Process: A Function of Information and Knowledge, JACQUELINE ANDERSON, *CONSAD Research Corporation, 250 Broadway, New York City.*

The optimal allocation of decision-making for planning between central and local decision-makers is a function of the information and knowledge available to each set of decision-makers. A conceptual model is used to determine whether the optimal planning process is a centralized or localized activity by examining alternative assumptions about the states of information and knowledge. A comparison is made of the relationship of this formulation of the planning process with the decomposition formulation.

TA1.3 Syndrome: the Pathologically Work-Oriented Manager, ALBERT PORTER, *San Jose State College, San Jose, California.*

Managers, particularly chief executives, commonly exhibit a behavior pattern of such all-out commitment to work and to career-oriented extracurricular activities as to result in virtual exclusion of family, non-career hobbies, and leisure. Such a behavior pattern is considered pathological since it appears to be associated with physical breakdowns such as coronary heart disease, mental breakdowns such as psychotic disorientation, personal crises such as sharp grief and remorse with respect to grown children who are virtual strangers; it is pathological also because it appears to contribute to rigidities and obsessions of the organization in which the manager is working. The behavior pattern would seem to result from a mutually-reinforcing resonance between certain of the individual's inner human qualities and certain of the organizational realities in which he operates. To identify this behavior pattern for clinical and research purposes in management science, the term Hopkins Syndrome is proposed because Ralph Hopkins, in Sloan Wilson's *Man in the gray flannel suit,* not only illustrates several facets of the syndrome with clarity and sensitivity, but is fictional. In elaborating Hopkins Syndrome together with possible causes and alleviations, reference is made to the literature of medical science as well as the behavioral sciences and their organizational branches.

TA1.4 The Other Side of the Fence, ROBERT G. BROWN, *Curtiss-Wright Corporation, Wood-Ridge, New Jersey.*

After twenty years of leading military and commercial operations research projects as a professional analyst, in October of 1967, I joined the Curtiss-Wright Corporation as Executive Director of Operations Services, with line responsibility for production planning, materials handling, manufacturing engineering, plant engineering, quality assurance and inspection. This paper is a review of the first six months' efforts to sponsor operations research in manufacturing areas of an important aerospace corporation, with special reference to the coordination of systems across all divisions of the corporation, and the integration of Marketing, Administration and Engineering in enhancing the profit centers capabilities to carry out their customer-satisfaction mission.

TA1.5 Measures of Association in Business Research, MICHAEL PERRY, *Oklahoma State University, Stillwater, Oklahoma.*

Disclosing association between variables is one of the major goals of any research, and it is very desirable to be able to measure it quantitatively. Measuring "association" will be helpful not only for theory construction, but also for evaluating performance of prediction tools, such as discriminant functions or Bayesian analysis. Tests of significance (e.g., Chi-square test) are often used as measures of association, but they are not appropriate for this purpose. Although they indicate "independence," they do not measure *degree* of association. Instead, some other measures, based on probabilistic interpretation of predictive activity, are surveyed and general criteria for choosing among different kinds of measures of association and for interpreting their meaning are suggested. The objective is to simplify the choice and to clarify the interpretation of association measures both in theory and in practice.

TA1.6 The Contributions of Decision Theory to Management Thinking, LAWRENCE HARRIS, *New York University, 100 Trinity Place, New York.*

This paper discusses the contribution that a decision theoretic approach to the solution of decision problems can make to management thinking. The paper describes the assistance that Decision Theory gives in thinking about problem formulation. It then describes how the use of the Standard Gamble can encourage the in-depth examination of qualitative, often psychological, consequences. Finally, the paper discusses how Decision Theory encourages the general philosophy of the uncertainty of the entire environment and the probabilistic nature of all information. Throughout the paper, a variety of pertinent examples is described.

TA1.7 An Approach for Designing a Fundamental Information System, A. F. MORAVEC, *Booz-Allen Applied Research, 100 W. Monroe Street, Chicago, Illinois.*

Management decision making in this new data processing era can be made at a level of information availability never before dreamed of. This means not just more information faster but the present trend is toward mathematically pre-analyzed and pre-selected information from which meaningless data have been culled. If management is to manage, the decision makers must take the lead in understanding, designing and approving the model of the fundamental information system. Two problems plague both managers and data systems analysts. The first problem is that of defining the concepts for an information system of the Firm and the second is related to it, that is, how does one go about designing and developing this system. The purpose of this paper is to provide an approach for developing the basic information system, and also to provide one technique that can be used successfully in both designing the system and insuring that the system contains the essential data required to perform all the basic operations and functions of the Firm.

TA1.8 Generalized Data Base Systems as an Aid to Quantitative Thinking, T. WILLIAM OLLE, *RCA Electronic Data Processing, Cherry Hill, New Jersey.*

This paper describes the rationale behind the development of generalized data base systems. The established functional approach to using computers, based on

conventional procedural programming languages, is compared with the emergence of the data base oriented approach which provides a non-procedural language. This may be used by non-programmers to retrieve information from a data base and to keep the data content timely. As decision makers find themselves with better access to more information, they need to cultivate an appreciation of defining exactly what they need in a decision situation. If the hypothesis can be made that any informative subset of a data base is immediately retrievable, then the decision maker has to learn how to identify such sub-sets. Since data collection and maintenance are expensive in any environment, quantitative decisions are called for in specifying exactly which data items are to be stored and maintained in a data base. As use of the data base progresses, data can be collected by the system about the frequency of use of the various data items present. The collected data can provide information on which to base decisions to purge the file of never used items. A more sophisticated, and somewhat futuristic, system could be designed to coordinate inputs on data collection areas in which the overall system is lacking. Based on human decision, the data base can then be revised or reorganized to accommodate the data items which have been newly identified as required. Three levels of interface between man and machine are identified and compared with the existing one of the professional programmer. The importance is discussed of the middle level of interface in which any sub-set of the data base can be identified to provide a basis for quantitative decision making.

TA1.9 Effective Information Systems for Industrial Business Management, RICHARD W. BARNES, BEN W. SMITH and J. E. MITCHELL, *The Dow Chemical Company, Midland, Michigan.*

For industrial companies above a nominal size there exist levels of management which are more concerned with the total business than they are with specific functional operations. Most of the industrial management information systems designs reported in the literature to date have dealt with the functional operations (e.g., production scheduling, inventory control, PERT, distribution optimization, etc.) and relatively little has been reported on information systems for overall "Business" management. This paper describes research done to identify the information needs of industrial management for business planning and control. Types of systems currently being implemented are discussed. Guidelines for successful implementation are given.

TA1.10 Inventory Record Accuracy, D. A. SCHRADY, *Naval Postgraduate School, Monterey, California.*

We address the subject of inventory record accuracy and its effects on optimal inventory management. An error exists if the item records do not agree with what is actually on the shelves in the warehouse. Three types of errors are possible: quantity errors, location errors, and identity errors. These errors can have a significant influence upon inventory management as procurement decisions are normally based on what the records indicate rather than on actual on-hand quantities. Physical inventories (counts) are taken periodically for the purpose of bringing records and actual quantities and locations back into agreement. However,

studies have shown that the physical inventorying process is itself error producing. We will address three problems: (1) obtaining a meaningful notion or operational definition of inventory record accuracy, (2) the strategy of obtaining a given level of record accuracy at minimum cost, and (3) development of the notion of the optimal error rate—that error rate which minimizes the sum of penalties incurred from use of inaccurate records and the costs of obtaining record accuracy.

TA1.11 Computer Generation and Plotting of Discrete Probability Distributions, GENE A. FINKLER, *Equitable Life, New York, New York.*

This paper is devoted to discrete probability distributions. (A subsequent paper on continuous probability distributions will be presented at the November, 1968 national meeting of ORSA.) There are seven discrete probability distributions that are considered here: the BINOMIAL, the MULTINOMIAL, the HYPERGEOMETRIC, the GEOMETRIC, the PASCAL, the NEGATIVE BINOMIAL, and the POISSON distributions. A detailed study is made of each of these distributions, enumerating its characteristics and the advantages and disadvantages of its use. In order to see how each of these theoretical distributions can actually be applied in real-life situations, examples are given of problems that typically occur in a large corporation. Each problem is analyzed to determine which distribution is appropriate and to determine what values of the parameters are needed to specify the shape of this distribution. Next, several descriptive measures are calculated; these consist of the expected value, the standard deviation, the variance, the skewness, and the kurtosis of this distribution. Following this, computer-produced plots are presented which depict the graph of the probability function and the graph of the cumulative distribution. After this theoretical examination of the sample problem, a series of stochastic variates is generated. Each of these variates possesses the characteristics of the problem and is in a form that can be used directly by simulation models. Finally, a computer-produced histogram is presented which depicts the frequency distribution of these stochastic variates. In addition, it also calculates the total, the mean, the standard deviation, and the upper and lower limit of the range. A listing of the complete computer program for discrete probability distributions is given in the Appendix.

TA1.12 The Cost and Schedule of a Computer Program, MUHAMMAD NAQI, *Computer Sciences Corporation, Richland, Washington.*

This paper is an attempt to systematically divide the activities involved in implementing a computer program into distinct phases. The end of each phase marks the accomplishment of a task and is a point to review the progress. Enclosed within a phase is the network of the activities required to accomplish the task. PERT is applied to the network to arrive at the schedule. The cost of the entire project is worked out by costing the units of time spent in the phase. In order to apply the technique successfully, it is imperative to develop standards for costing the units of time for given allocations of man-power resources. The application of this technique is not limited to the projects planned for long durations. The author has used it as a tool on projects lasting three to four weeks. The results of each review are revealing. Even if everything is on schedule, a review still helps in allocating time and resources to the future activities.

TA1.13 Computer Planning and Optimization of Automated Manufacturing Processes, P. BRUCE BERRA and MOSHE M. BARASH, *Purdue University, Lafayette, Indiana.*

A computer based system that plans and optimizes the manufacture of components on automated machines is presented. The input to the system consists of information regarding the machining operations that are to be performed in the manufacture of the component. Utilizing this information the system selects a member from the set of automated machines that can perform the operations. It then selects tooling based upon the machine parameters and raw material characteristics. The optimum technology parameters are determined based upon the criterion of minimum time of manufacture. Cost and time values are calculated for the particular machine under consideration. If more than one machine is available, in the set of machines that can perform the work, the system repeats the process for each machine. The output from the system consists of optimum technology parameters, tooling, costs, times, etc., for each machine. Thus, the optimum machine can also be selected. The output is then utilized to generate the necessary controls for the automated manufacture of the component. Examples are given for a part family of turned components.

TA1.14 Integrating Scientific and Behavioral Science Disciplines for Management Decision Making in a City Government Datacenter, GILBERT M. GOODFRIEND, *Daniel D. Howard Associates, Inc., 307 N. Michigan Avenue, Chicago, Illinois.*

Many city governments are victims of their own political environment, where there is a multiplicity of computing equipment as well as awkward and frequently ineffective use of that equipment. Decision-making in recruitment, selection of people, and application of hardware is frequently the responsibility of managers who are susceptible to pressures which decrease the probability of high efficiency. By integrating behavioral science (personnel appraisal) disciplines with scientific disciplines (i.e., statistics, network planning) in a unique urban environment, the development of a new "system" of operation is possible. This operations research approach to developing a facility serving all departments of the city has the potential of breaking down old barriers to reduce hardware costs and improve work output of personnel. This facility can provide an atmosphere for making great strides in the application and use of computers in a social-political environment thus enabling the departments of the city to better serve the citizens. This multiple discipline approach is taking place in the centralization of computer resources within the City of Chicago Datacenter.

TA1.15 Toward Aggregate Models of Educational Systems, BANI K. SINHA, SHIV K. GUPTA and ROGER L. SISSON, *Management Science Center, University of Pennsylvania, Philadelphia, Pennsylvania.*

Growing complexity of educational systems implies that the administrators of these systems can benefit from operations research. Operations research can aid business decisions in schools, but the more vital problem is to aid in the basic educational decisions: particularly the allocation of resources to educational activi-

ties. Two models are proposed as initial efforts in this direction. The aggregate effect of resource allocation on student achievement in a school is given by

$$D = \sum A_i \eta_i T_i^{\mu_i} S_i^{V_i} M_i^{\eta_i}$$

where D is an index of student achievement, T_i is the teacher-student ratio, S_i is the space per student, and M_i is the dollar expenditure of materials per student, all for grade i. A_i, μ_i, V_i and η_i are constants. A second model calculates η_i, the number of students in grade i by means of flow equations. The consequences of these models are explored in examples.

TA1.16 The Application of Logistic Principles to the Purchase, Storage and Distribution of Surplus Agricultural Commodities, ROBERT M. FLORY, *Consumer and Marketing Service, U.S. Department of Agriculture, Washington, D.C.*

Each year the U.S. Department of Agriculture purchases large quantities of surplus foods to support farm prices. These are distributed through a federal-state-local distribution system to eligible schools, institutions, and needy families. Optimum utilization of these foods requires both a complex, nation-wide information system and the application of modern logistic principles. Some of the recent applications to these operations are: (1) the use of linear programming in bid and shipping cost analyses, (2) the development of algorithms for the determination of optimum storage and shipping quantities, reorder points and buffer stocks, (3) the use of standards and automated exception reports for the monitoring of operations and (4) the determination of more adequate informational needs for evaluating program effectiveness. The need for preserving the independence and autonomy of the respective federal, state and local jurisdictions greatly increases the complexity of the information system.

TA1.17 On The Modeling of Relationships Between Performance and Resource Management in an Urban School District, MARTIN STANKARD JR., *University of Pennsylvania, Philadelphia, Pennsylvania.*

Top management in many urban public school systems is calling upon systems analysts and operations researchers to help in making their schools more effective. Recently considerable effort has been devoted to improving the planning and resource allocation functions in urban school systems. A critical research problem in this area is the development of models which relate an acceptable index of school performance to management policy under a variety of environmental conditions. This paper reports one approach to the problem. The process of education is defined by a qualitative concept. The key concept is that education is a process of communication. The definitions include factors controllable by management and factors determined largely by the non-school environment. In the model development, the assumed relationships among these factors (variables) are first listed and then a mathematical analog to the statements is developed. At the present stage of development the model relates changes in achievement test scores (on a school by school basis) to pertinent resource input factors. Data from a sample of schools has been used to estimate parameters and to test the model's ability to predict per-

formance from management policy. The results of the empirical work are presented. Practical implications both for further research and for school system administrators are also discussed.

TA1.18 A Case History of Education for Military Operations Research, HAROLD TOMBACH, *Northrop Corporation, Beverly Hills, California.*

The history of the build-up of the ORG, the Operations Research Group of the German Ministry of Defense by a team of OR scientists of the Northrop Corporation is presented. From 1961 to 1968 the Northrop team educated and trained German scientists, who, without exception, had no experience whatsoever in military OR to become effective analysts, project leaders, and group heads. Today the ORG employes about 150 German scientists capable, as an entity, to handle effectively any problem within the spectrum of military OR. The pragmatic approach used to achieve these results and the difficulties encountered are discussed. Finally, an analysis of the educational process, in the light of the experience accumulated, is presented.

TA1.19 A Test of Delivery Truck Route Design by Computer, LEONARD W. SCHRUBEN, *Stanford University, Stanford, California,* and RUTH E. CLIFTON, *Kansas State University, Manhattan, Kansas.*

A system for routing feed delivery trucks has discovered distance savings of as much as 20 per cent when compared with the actual routes selected under operating conditions. Feed manufacturing firms from New England to California supplied information on actual deliveries. An ex-post routing of the same trucks to deliver the same quantities to the same receivers was made and the distance compared with actual distance traveled. Typical reductions were from 8 per cent to 12 per cent. In no case did the actual routing show fewer miles than the routes discovered ex-post. The system is computerized to enable a dispatcher to design delivery routes and issue loading instructions for each truck as soon as orders for a given day are known. Trucks need not be the same size, and quantities to each customer may vary. The system not only identifies the set of stops which constitute the route, but indicates the sequence of stops within each set. In common with other procedures to solve traveling salesman problems, this system has no mathematical proof that the computed distance is a minimum. Consequently, the best test of suitability for commercial application is to compare results with actual solutions of experienced dispatchers who know their territory.

TA1.20 Shortest Route Models for the Allocation of Inspection Effort on a Production Line, LEON S. WHITE, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

Two shortest route models for determining where to allocate inspection effort on a production line are developed for the cases where this effort is unlimited or limited in its availability. A production line is defined as an ordered sequence of production stages, each stage consisting of a manufacturing operation followed by a potential inspection station. Items flow through the line in batches and may incur defects at any stage. Defects are assumed to be repairable or non-repairable. The

defect generating process at any stage is taken to be an independent Bernoulli process with a known parameter. Two levels of inspection effort may be applied at any stage: no inspection or 100% inspection. Thus, both models are used to determine the stages at which batches are to be 100% inspected. A general cost structure is postulated first for the case where items with repairable defects are immediately repaired and items with non-repairable defects are discarded, and then for the case where all items found to be defective are replaced immediately with non-defectives. An expected cost per batch criterion is used to determine an optimal inspection plan in all cases. Examples are included.

TA1.21 Exponential Smoothing with Automatic Weight Assignment, THOMAS THAMARA, *Harris Trust and Savings Bank, 111 West Monroe, Chicago, Illinois.*

We have designed a forecasting system which is a modification of Exponential Smoothing with a built in variable weight structure which will automatically shift the assignment of weights to the estimates of the steady state (permanent) components of the forecast as the underlying phenomenon changes. This model makes the prediction better for activities that shift up or down in volume by detecting legitimate shifts in the system forecasted. However, its forecast would be no different from that of a regular exponential smoothing model for data that have steady movements. Of particular importance is that we are using it successfully for forecasting manpower requirements for the various divisions in our bank, where all published systems have failed.

TA1.22 A Location-Allocation Model With Transport, Fixed and Volume-Related Costs, MICHAEL G. SOVEREIGN, *University of Illinois, Urbana, Illinois.*

The optimal number and location of distribution centers can be phrased as either the number and location of plants to serve a set of markets from a set of raw material sources, or as the number and location of warehouses to serve a set of markets from a set of plants. Efficient cost minimizing models with a realistic cost structure are lacking despite approaches along iterative, integer programming, heuristic, dynamic programming, gradient search and physical lines. A probabilistic search or discrete optimizing model with transport, fixed, and volume-related costs with economies of scale is described and computational results are discussed. Suggestions for methods using more of the special structure of the problem are outlined.

TA1.23 Stochastic Programming, Optimal Control and the Repair Dispatch Problem, WILLIAM H. EVERS, *International Business Machines Corporation, 326 East Montgomery Ave., Rockville, Maryland.*

A network is considered in which the arcs represent transportation costs for repairmen and nodes potential repair points. A stochastic programming formulation is postulated in terms of the current and past states of the system. The objective function is derived by using transportation costs and incorporating the cost of constraint infeasibilities. Optimal control theory then allows a reduction of the stochastic program to an easily solvable assignment problem. Results of actual use of this algorithm in a large repair-dispatch facility are presented.

TA1.24 Replacement Rules for Partially Observable Equipment, DEV K. RAY, *Bell Telephone Laboratories, Inc., Holmdel, New Jersey.*

Optimal inspection and replacement rules are investigated for a simple piece of equipment which has a Markovian failure distribution. Although the true state of the equipment is not observable, indirect indications can be obtained by observing a quality characteristic. The probability distributions of the quality characteristic, conditional on the state of the equipment, are assumed known. The sequence of observations and replacement actions up to some time t can be summarized into a sufficient statistic $X(t)$ representing the probability that the equipment has failed by time t. For a given cost structure, the objective is to minimize the expected total discounted future cost up to an infinite horizon. Two models are considered. In the first model, observations are assumed to be taken periodically and the optimal replacement rule specifies a constant $\mu \in [0, 1]$ such that at any time t, if $X(t) > \mu$, the equipment is replaced immediately. In the second model, observation costs are allowed. Depending on the value of $X(t)$, the optimal policy consists of specifying when to take the next observation or the next replacement action. Computational algorithms are presented to determine the parameters of the optimal policies for both models.

TA1.25 Optimal Production Planning of Nonlinear, Multiproduct Systems, E. STANLEY LEE, *Kansas State University, Manhattan, Kansas.*

The analytical and computational problems in the optimization of production scheduling and inventory control of a nonlinear, multiproduct, interconnected, manufacturing operation are discussed. Since these production planning problems are generally nonlinear and multidimensional, they can seldom be solved analytically. Although dynamic programming and the calculus of variations are two powerful approaches for solving these optimization problems numerically, both techniques have been limited to problems with a small number of state variables. This is known as the dimensionality difficulty in dynamic programming and as the boundary value difficulty in the calculus of variations. The recently developed computational techniques such as the state increment dynamic programming and the quasilinearization technique have been used successfully to partly overcome these difficulties in the literature. It is shown in this paper that these computational techniques can also be used to solve the nonlinear multiproduct production scheduling problem. An example is used to illustrate the approach. Other optimization techniques such as the maximum principle and the functional gradient technique are also considered. The advantages and disadvantages of these recently developed computational techniques are discussed.

TA1.26 Closed Networks of Queues with Time Lags, MORTON J. POSNER, *University of Toronto, Toronto, Canada.*

The study of closed networks of queues involves the flow of a finite number of items or people among a number of "stations" at which points congestion may occur. When a unit completes "service" at one of the stations, it moves to some other in accordance with a fixed probability distribution associated with the station it is leaving. Such queuing networks are investigated under the assumption that the

time required for a unit to move from one station to another is a random variable. By introducing suitable supplementary variables, this system is modelled as a Markov process with states having a combination of discrete and continuous components. The structure of the resulting steady state solution is analyzed and shown to be similar to that for the corresponding system with no time lags. From the form of the solution it can also be deduced that all the time lags in the system can be combined to form a "virtual" station having a number of interesting properties. Furthermore, it is shown that the entire system with time lags can be transformed from a network of N stations into a cyclic queuing system with $N+1$ stations, and no time lags. The exact absolute probabilities for the number of units at each station is found, and an approximating technique is outlined for obtaining these probabilities in a simpler manner.

TA1.27 A Dual Maximum Principle for Discrete-Time Linear Systems with Economic Interpretation, C. DUNCAN MACRAE, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

A discrete-time linear optimal control problem with given terminal horizon, state-control constraints, and fixed end points is set forth. This primal control problem is reformulated as a primal linear programming problem. Corresponding to the primal linear programming problem is a dual linear programming problem. The dual linear programming problem is reformulated as an optimal control problem which is the dual of the primal control problem. A dual maximum principle is proved with the aid of the duality theory of linear programming where the dual of the Hamiltonian of the primal control problem is the Hamiltonian of the dual control problem. The analysis is generalized to include variable end points. An economic interpretation of the results is presented and a number of applications are discussed.

TA1.28 Optimal Search for a Maximum Using an Information Theoretic Approach, MICHAEL HEYMANN, *Mobil Research and Development Corporation, Princeton, New Jersey.*

The problem of estimating an optimal interval containing the location of the maximum of a unimodal function is solved for the case when an arbitrary probability density function for the distribution of the maximum is given. The payoff of the estimation is taken to be the expected value of the Statistical Information gained by the search. Both the sequential and the simultaneous search problems are discussed. When the experiments are performed sequentially, the optimal strategy is a generalized Fibonacci search, which in the special case of a uniform probability density function reduces to the well-known minimax solution. When the experiments are performed simultaneously, the following optimal strategies result. For an even number of experiments the optimal strategy selects an interval estimate, containing the maximum point, for which the maximal a priori probability of containing this maximum is minimized. When the probability density function is uniform, the optimal strategy minimizes the maximal length of the interval estimate. For an odd number of experiments an unsymmetric search pattern results.

TA1.29 A Model of Rational Competitive Bidding, MICHAEL H. ROTHKOPF, *Shell Development Company, Emeryville, California.*

This paper presents a mathematical mode of the bidding process that deals explicitly with the uncertainty of the bidders about the value of the subject of the auction. By dealing with this often ignored factor, it obtains equilibrium strategies and profits as a function of the number of bidders, the relative values they attach to the subject of the auction and their accuracy in estimating it. Models are developed for both highest-bid-wins and lowest-bid-wins auctions.

TA1.30 Some Effects of Advertising on Optimal Inventory Policy, FREDERIC A. MIERCORT, *Research Analyses Corporation, McLean, Virginia.*

An inventory model which includes the possibility of advertising is investigated. This model is a stochastic inventory model with linear ordering costs and increasing, convex holding and penalty cost functions. Advertising is treated as follows. The existence of a quantity called goodwill is assumed, the amount of which can be increased by advertising. The existence of b units of goodwill has the effect of adding $\psi(b)$ units to demand, where ψ is an increasing, concave function. A discount factor θ is assumed, which determines the decrease in goodwill from period to period. Thus, if there is an amount b of goodwill at the start of the present period, there will be an amount θb at the start of the next period, which one can then increase by advertising if one chooses. Both finite and infinite horizon results are obtained for this model, and the optimal policy is similar to the usual single critical number policies. Results are also obtained for several generalizations of the model. One generalization considers the situation where the added demand due to advertising is not deterministic, but stochastic in nature, and a second generalization includes a set-up cost in the ordering cost function.

TA1.31 A Cost Effectiveness Model, ROY D. HARRIS, *The University of Texas, Austin, Texas.*

This paper consists of an illustrative problem on the methods of cost-effectiveness analysis. In particular, it contains: a description of the structural or theoretical framework for cost-effectiveness analysis and; a computer model which may be used as an illustrative "hands on" exercise on cost-effectiveness analysis. The first section of the paper describes the basic cost-effectiveness formula and briefly discusses the system concepts which underlie cost-effectiveness analysis. The latter sections present a computer model to be used for determining measures of benefits and cost for a particular military problem. The methodology illustrated for this particular problem is general, however, and may be applied to any situation which requires evaluation of alternative ways of performing a major task.

TA2.1 *Tiger, an Air/Ground Tactical Combat Simulation, LOREN RIECHERS and ROMAIN MEES, *Planning Research Corporation, 1100 Glendon Avenue, Los Angeles, California 90024.*

The purpose of the TIGER model is to describe the interaction between strike aircraft and various ground defenses. The model is constructed in efficient subroutine form allowing each function to be carried out separately and permitting

easy modification for program growth as new defenses and advanced missiles are introduced. TIGER reflects most of the actual performance characteristics of the SAMs, AAAs, ASM, and strike aircraft in a detailed engagement. The outcomes from TIGER are used as inputs to PRC's combat theater simulation model (TEAM) or to construct effectiveness functions for PRC's optimizing program (TAME). In addition, TIGER is incorporated as a principal subroutine in the new "DISARM" simulation for the STD/ARM operational analysis study program. TIGER is currently in use in studies of tactical operations of armed helicopters, studies of defense suppression by anti-radiation missiles, and in a family of ASM operational application studies.

TA2.2 *Simulation Techniques for Analyzing Air Combat Systems, TERRELL E. GREENE, *The RAND Corporation, Santa Monica, California.*

In designing fighter systems for tactical air-to-air combat the dynamics of encounters between highly maneuverable fighter aircraft must be taken into account. In particular, the influence of the conditions of close-in maneuvering combat must be considered, since they place stringent requirements on system capabilities. Rapid changes in altitude, velocity, relative angular bearing, and relative range typify close-in fighting. There are severe conflicts among desired design characteristics of a tactical air-to-air combat system, and the designer must decide on the preferred compromise among a wide variety of possible choices. An informed decision on system design requires quantitative, time-history descriptions of the major geometric and aerodynamic parameters of representative air-to-air combat encounters. It is also necessary to make quantitative comparisons of the performance of alternative systems in realistic combat situations. Various methodological approaches are available, each with its advantages and limitations. Among the available methods are analytic solutions, simplified simulation models, flight tests, and detailed dynamic simulations. RAND has developed a detailed computer simulation model to represent the motions of up to 3 aerodynamic vehicles in 3-dimensional flight. Each vehicle, which may be an aircraft or a missile, moves with 6 degrees of freedom. Tactics simulated are reasonably close approximations of air combat tactics flown by fighter aircraft, and vehicle performance is represented with a high degree of realism. The simulation is used both to generate detailed dynamic descriptions of air-to-air combat and to permit comparison of alternative systems.

TA2.3 *Comments on Aircraft Kill Probability Models, A. V. FEND, *Stanford Research Institute, 333 Ravenswood, Menlo Park, California.*

In recent years many computer simulation models have been designed to estimate the probable attrition of aircraft due to the effects of ground fire from visually controlled small caliber weapons. All models make use of certain generally accepted simplifying assumptions about the gunner's decision to initiate a fire mission, the effect of accumulated damage due to successive hits on target, and other parameters and decision rules. However, a very serious and controversial issue is raised by the fact that most existing models are based on the assumption that the round to round miss distances in a firing sequence are statistically independent.

This paper presents some specific gun model alternatives and describes certain empirical and theoretical results which reflect on the validity and usefulness of their underlying assumptions.

TA2.4 *Tactical Employment Analysis Model, GENE ROSHOLT and HARRIS DALRYMPLE, *Planning Research Corporation, 1100 Glendon Avenue, Los Angeles, California 90024.*

The Tactical Employment Analysis Model (TEAM) is a general-purpose, event-oriented response model implemented in the SIMSCRIPT language. The model assigns specified sets of tactical vehicles (each having specific attributes) to perform required tasks across a theater operation. The performance of the task is both a function of the task itself and of the vehicles utilized to perform the task. The model operates in simulated clock time and Cartesian (map) coordinates, the dimensions and units of which may be specified at will. Variations in the performance of each task may occur as a function of season, time of day, weather, or other such parameters. The vehicles and tasks to be performed will, in general, have attributes such as location, speed, endurance, payload, response-time, reprovisioning requirements, survivability, request time, abort time, and an ordered list of vehicle types which can perform the task. Various pools (as a function of vehicle type and location) may be generated. Task priorities may be assigned resulting in vehicle delay or diversion. Output data of flexible nature and format may be obtained regarding time, vehicle, or task-dependent parameters. Statistical processing and presentation of such data is also available.

TA3.1 *Some New Views on the Common Criteria for Capital Budgeting Decisions, H. MARTIN WEINGARTNER, *University of Rochester, Rochester, New York.*

The criteria commonly used or recommended for investment project selection have generally been analyzed from a fairly narrow economic perspective. The assumptions under which any of them are strictly valid are often not met. More important the problem faced by the decision maker is never analyzed to understand the role played by these scalar measures of attractiveness. This paper discusses these issues in some detail, suggesting how the problem ought to be viewed, and the role of the common criteria in their solution.

TA3.2 *The Risk of Bankruptcy: The Third Discriminant in a Three-Discriminant Capital Budgeting Model, JAMES MCN. STANCILL, JR., *University of Southern California, Los Angeles, California 90007.*

Using the (mean) expected rate of return ($\bar{R}$) as the first discriminant, and the coefficient of variation of the expected rate of return ($CV_{\bar{R}}$) as the second discriminant, this paper will direct attention to a third discriminant (B) which has been a source of concern but has heretofore been undefined. For want of a better term, this B will be called the risk of "bankruptcy" or a measure of the ability of a proposal (or a set of proposals) to evoke a position of cash insufficiency and, thus, jeopardize the continuity of the firm. This B discriminant also has the property

of taking account of the unusually large proposal (after a discussion of what is connoted by the absolute size of a proposal), and the proposal which has a satisfactory $\bar{R}$ and CV_R but has associated with it negative cash flows, say in the early period of the economic life of the asset. Additionally, B permits explicit recognition of the fact that some proposals, if accepted, would have explicit financing associated with them, e.g., a mortgage on realty or lease payments. While still in an elementary stage, B should stimulate additional thought on questions usually ignored in capital budgeting models.

TA3.3 *Intertemporal Bank Asset Choice With Stochastic Dependence, A. CHARNES and S. C. LITTLECHILD, *Northwestern University, Evanston, Illinois.*

This paper extends existing models of inter-temporal bank asset management in the cases where demands for loans of particular categories, and the repayments thereof, are not known with certainty. We represent them by random variables jointly dependent upon the level of economic activity. Feedback relationships between loans and deposits, and between loans over time, are introduced explicitly. In addition, the Federal Reserve Board's suggested leverage requirements are replaced by chance constraints pertaining to considerations more directly involved in bank asset management, such as overall default rates, risk spreading and the desirability of meeting demands for loans by favoured classes of customers. This framework arose from discussions with officers of a local Chicago bank.

TA3.4 *Using Scored Research Data in a Bank Marketing Problem, MICHAEL PHILLIPS, *First National City Bank, 880 Third Avenue, New York, New York 10022.*

Data in the form of scores on a zero-to-one scale are used as input to a model. The model is constructed to determine the effects resulting from many possible marketing decisions on a certain market share of a bank. The data is acted upon to produce derived scores much in the way answers to questions on a quiz are scored, weighed and added to produce a score for the quiz. However, in this model statistical methods are used to combine the inputed scores. A diagrammatic approach is shown as an attempt towards clarity for non-technicians. An example of this method is given concerning a retail banking decision to change its checking account charges.

TA3.5 *The Synergistic Implications of Operations Research Projects in Banking, RANDOLPH JENKS, *Security First National Bank, Los Angeles, California.*

The application of operations research techniques to banking has demonstrated numerous areas for profitable work. Each project area can and usually is justified on the basis of an immediate or near-term payout. Viewed from a systems standpoint, the quantification and modeling of segments of a bank facilitates similar work in related areas and can be planned to accomplish larger objectives such as management control and information systems on a "pay as you go" basis. The ramifications of typical OR banking projects are reviewed in this larger context.

TA4.1 *Inconsistency of the Maximum Likelihood Estimator in Certain Reliability Problems, A. W. MARSHALL and F. PROSCHAN, *Boeing Scientific Research Laboratories, P.O. Box 30981, Seattle, Washington 98124.*

The maximum likelihood estimator (MLE) is known to be consistent under mild regularity conditions in a number of standard cases. In this paper, it is shown that the MLE can yield inconsistent estimators in several quite important, naturally occurring reliability models. These include the following cases: (a) The average failure rate is increasing (alternately, decreasing) (b) The failure rate is bounded above and/or below by known functions. Thus the method of maximum likelihood must be used with caution.

TA4.2 *Evaluation of System Readiness and Reliability Estimation Procedures, D. P. GAVER, JR., *Carnegie-Mellon University, Pittsburgh, Pennsylvania.*

A system's readiness is measured by the probability, R, that it will be operative when needed; its reliability by the probability, r, that it remains operative throughout the time of need. This paper investigates the statistical properties of various estimates of R and r. First, properties of point estimators of readiness and reliability for simple systems having exponential failures and repairs are reviewed, assuming the availability of limited sample data. Maximum likelihood and Bayes estimators are exhibited and examined with respect to bias and squared error criteria, and the effect of bias removal schemes (e.g. the Quenouille-Tukey jackknife) are illustrated. Next, the effects of model deviations, data pooling, and properties of estimators with adaptive properties are investigated. Finally, some discussion of redundant and spare-equipped systems is given.

TA4.3 *Optimal Control of a Service System, C. R. GLASSEY, *Department of Industrial Engineering and Operations Research, University of California, Berkeley, California,* and R. M. THATCHER, *Boeing Scientific Research Laboratories, Seattle, Washington 98124.*

The particular service system studied is characterized by the following: a homogeneous poisson arrival stream of customers; the jth customer adds an amount V_j to the inventory of raw material which is consumed by the processing plant at rate r_1 or r_2 to be chosen by the decision maker; the random variables V_j are independent and identically distributed, and the cost per unit time is a constant times the raw material inventory plus a term dependent on the chosen rate. If the system is operated at a fixed rate, the raw material inventory behaves like the virtual waiting time of an $M/G/1$ queueing system. Assuming that the slower processing rate exceeds the mean arrival rate of raw material, a stationary control policy can be found that minimizes the expected long-run average cost rate. A procedure for computing such an optimal control policy involves numerical inversion of the Laplace transform of the virtual waiting time distribution.

TA4.4 *Optimal Ordering and Rationing Policies in a Nonstationary Dynamic Inventory Model With n Demand Classes, DONALD M. TOPKIS, *Yale University, New Haven, Connecticut.*

Considered are some problems associated with an inventory system in which demands for stock are of n classes of varying importance. When demand from a

given class arrives one must decide whether to satisfy it or to not satisfy it and conserve stock for possible use later to satisfy demand from a more important class. Conditions are given under which the optimal rationing policy between successive procurements of new stock is determined by a set of critical rationing levels such that at a given time one satisfies demand of a given class only if no demand of a more important class remains unsatisfied and as long as the stock level does not fall below the critical rationing level for that class at that time. Conditions are also given under which the optimal procurement policy at a given time is determined by a single critical level in the usual manner. Further conditions are given which assure that the optimal rationing and procurement policies may be determined myopicly.

TA4.5 *Optimal Policies for a Two Product Inventory System with Negotiable Lead Times, GORDON P. WRIGHT, *Department of Industrial Engineering and Management Sciences, Northwestern University, Evanston, Illinois 60201.*

A two product periodic review dynamic inventory problem is considered. At the beginning of each period two decisions are made for each product. How much to "normal order" with a lead time of λ_n periods and how to "emergency order" with a lead time of λ_e periods, where $\lambda_e < \lambda_n$. Demands in the periods are vector random variables with known probability density functions. The ordering decisions are based on certain costs, namely the procurement costs for both methods of ordering and the holding and penalty costs. It is assumed that there is a budget constraint which restricts the total amount that can be ordered or produced during the period to fill both normal and emergency requirements. Common examples of such a constraint are systems where both products are produced on the same set of machines and available machine time is limited, or both products require the same scarce material in their assembly. In this two-product system the essential problem is to determine the optimum allocation of the resource among the two products where any resource used for emergency production will decrease the amount of resource available for normal production. The optimal emergency ordering policy is shown to have a simple form under quite reasonable assumptions on the ordering costs. Both the normal and emergency ordering policy is characterized for the one and N-period problem.

TA4.6 *Minimum Concave Cost Solution of Leontief Substitution Models of Multi-Facility Inventory Systems, ARTHUR F. VEINOTT, JR., *Department of Operations Research, Stanford University, Stanford, California 94305.*

The paper shows that a broad class of problems can be formulated in terms of minimizing a concave function over the solution set of a Leontief substitution system. The class includes deterministic single and multi-facility economic lot size, lot size smoothing, warehousing, product assortment, batch queueing, capacity expansion, investment-consumption, and reservoir control problems in which all cost functions are concave. For such problems the optimum occurs at an extreme point of the solution set. The extreme points are characterized in each case by using the characterization of the extreme points of the solution set of a Leontief substitution system. This approach enables most existing qualitative characterizations of optimal policies for inventory models with concave costs to be ob-

tained in a unified manner. Dynamic programming recursions for searching the extreme points to find one that is optimal are given for a number of cases. The only algorithms given are those for which the computational effort increases algebraically (instead of exponentially) with the size of the problem.

TA5.1 Large Networks of Buoys and the Traveling Repairman Problem, H. GOTTSCHALK, C. D. NELSON and A. J. PHILLIPS, *General Dynamics, P.O. Box 1950, San Diego, California.*

Present plans of the world's meteorological community call for a global atmospheric research program beginning in 1972. A world-wide, synoptic measurement grid is expected to be established as a part of the program. A major portion of the data collection stations will be occupied by automatic telemetering ocean buoys providing both meteorological and oceanographic data. General Dynamics Convair Division, in support of its "Monster Buoy" program, is performing system studies of the buoy networks involved. During these studies, the so-called "traveling repairman problem" was defined. The problem arises in selecting a cost-effective mix of routine and unscheduled maintenance operations for a large network of buoys. As opposed to the traveling salesman problem, it is characterized by "best" path selection through a dynamic network where the benefits associated with arriving at particular nodes are unequal and changing. In this case, the benefit at each station is a function of the station's mode of operation, the time of arrival, and the proximity to other stations which have randomly (in time and space) assumed related operational modes. On each trip, the repairman is constrained by the speed at which he can move, the number of repairs he can effect, the total distance he may travel, and the total time he may remain away from base. This paper describes the problem, and presents the results of some preliminary computer simulations.

TA5.2 A Branch and Bound Algorithm for Multi-dimensional Knapsack Problem, P. M. GHARE and LAWRENCE E. WALTERS, *Virginia Polytechnic Institute, Blacksburg, Virginia.*

This paper presents a Branch and Bound Algorithm for the solution of multi-dimensional knapsack problem. The algorithm is predominantly additive. Only a few multiplications and divisions are required for the preliminary preparation of the problem. The pushdown-stack technique is utilized to minimize the storage requirements, and two types of additional constraints are introduced to minimize the search. These additional constraints are: (a) a composite constraint for the initial solution and (b) a computed binding constraint introduced after each solution iteration. The reduced storage requirements enable a 32^k computer to handle a problem as large as 15 constraints and 250 variables. The second part of the paper describes the computational experience to indicate the effect of the dimensionality of the problem (i.e. number of constraints, number of variables, density of matrix, variation in coefficients, etc.) on the requirements of both the time for solution and storage space.

TA5.3 An Algorithm for Zero-One Programming and Its Application to Knapsack Problems, A. VICTOR CABOT, *Indiana University, Bloomington, Indiana,* and ARTHUR P. HURTER, JR., *Northwestern University, Evanston, Illinois.*

By starting with an all-integer zero-one linear programming problem, it is possible to develop a modified programming problem which provides a characterization of the basis corresponding to a feasible zero-one solution to the integer problem. This characterization is based on the number of variables equal to one in the feasible solution. An algorithm for zero-one programming, based on this characterization, is developed. The method uses the criterion function of the original problem as a constraint, then generates a sequence of feasible zero-one solutions, each with a greater value of the objective function. The algorithm terminates when no more feasible solutions can be found, indicating that the last feasible solution was the optimum. The main problem with the algorithm is that for problems with many constraints it is difficult to obtain feasible solutions even though we know that they satisfy the characterization. When the zero-one problem is of the one-dimensional knapsack type, the method is simplified since feasible zero-one solutions can be found by solving a linear programming problem. The algorithm is appealing because computer memory usage and possibly computer time increase linearly with the size of the problem.

TA5.4 Exact Solution of the Fixed Charge Transportation Problem, PAUL GRAY, *Stanford Research Institute, Menlo Park, California.*

In the fixed charge transportation problem, a fixed charge is associated with each route opened in addition to the usual transportation cost proportional to the amount of goods shipped. This paper presents an exact solution of this mixed integer programming problem by decomposing it into a master integer program and a series of transportation subprograms. To reduce the number of vertices that need to be examined, bounds are established on the maximum value of the total fixed cost, and feasibility conditions for the transportation problem are used extensively. Computational results show the method to be particularly suitable when the fixed costs are large compared to the variable costs.

TA5.5 A Modified Secant Technique for Convex Function Optimization, DAVID F. SHANNO, *University of Chicago, Chicago, Illinois.*

The secant method for the solution of a system of nonlinear equations is employed as a means of estimating the Hessian matrix for the purpose of accelerating the convergence of a gradient search technique for optimizing a convex function. In order to add computational stability to the method, at each step an optimum scalar parameter λ is added to the diagonal of the current estimate of the Hessian. The algorithm for updating the current estimate to the Hessian is modified to account for this scalar parameter. The extension of this method to linearly constrained problems is discussed.

TA5.6 Resolution of Gaps in Everett's Theorem, M. BELLMORE, J. J. JARVIS, *The Johns Hopkins University, Baltimore, Maryland,* and H. J. GREENBERG, *The Southern Methodist University, Dallas, Texas.*

H. Everett has generalized the use of La Grange's function when maximizing an objective function whose domain is restricted by stated subsidiary conditions. His "generalized multiplier method" cannot obtain the solution for all resource limitations. These unobtainable values he terms "gaps." The objective of this paper is to demonstrate how one may obtain these missing values (or get lower bounds) by extending the concept somewhat. This extension involves the choice of more arbitrary functions of the constraint and objective. This is also related to the concept of "created response" developed by Carroll and this relationship is presented. Numerical examples are included to illustrate new concepts.

TA5.7 Synchronization of Processes as Integer Programming Problems, LARRY E. STANFEL, *University of Florida, Gainesville, Florida.*

There is given a collection M of sub-processes, $M=\{M_1, M_2, \cdots, M_m\}$, where M_j has states $S_j = \{s_{j0}, s_{j1}, \cdots, s_{j,n_j-1}\}$, $j=1, \cdots, m$. Time elapses in discrete intervals, beginning at $t=0$, at which moment sub-process j may be made to occupy any of its n_j states, and if M_j is in s_{jq} at $t=k$, it must occupy s_{jp} at $t=k+1$, where $p\equiv q+1 (\text{mod } n_j)$. The state of process M, then, when M_j is in state r_j may be defined by $(s_{1,r_1}, s_{2,r_2}, \cdots, s_{m,r_m}) \in \times_{j=1}^{m} S_j$. Given M's initial state, its state at any future time point is determined. A typical synchronization problem, then, is to specify a set of initial states $s^0_{j,r_j} \in S_j$, $j=1, \cdots, m$, so that $(s^0_{1,r_1}, s^0_{2,r_2}, \cdots, s^0_{m,r_m}) \in \Gamma$ and that M remain in Γ a maximum number of consecutive time intervals, where $\Gamma \subset \times_{j=1}^{m} S_j$. Important variations of the problem occur when Γ is a function of time or in cases where the time points of interest comprise a set T of arbitrarily- or equally-spaced points, the objective being to maximize the number of successive elements of T at which M occupies a state of Γ. (Generalizations of this sort include familiar synchronization problems such as the traffic problem.) These and other classes of applicable synchronization problems are formulated as integer programming problems, and some computational aspects are presented.

TA5.8 Adaptive Experimentation and Control: I. Known Change Precision, E. GERALD HURST, JR., *General Electric Company, 6901 Elmwood Avenue, Philadelphia, Pennsylvania.*

A solution is presented for a control problem with discretely dynamic, stochastic, partially observable states in which the amount of experimentation at each stage constitutes an important control decision. A general dynamic programming formulation of the problem is specialized to the case with quadratic cost of error and proportional cost of experimentation. The optimal experimental policy at every stage is found to consist of a single critical number. It is noted that this structure corresponds to the optimal ordering policy for inventories with proportional ordering cost and convex operating cost. A set-up cost of experimentation is introduced, and a two-level experimental policy analogous to the (s, S) inventory policy is obtained.

TA5.9 Coordination of Parallel Activities Under Uncertain Demand or Activity Performance: Linear Programming Models of Markovian Decisions, HIROHIDE HINOMOTO, *University of Illinois, Urbana, Illinois.*

Cases are considered in which a group of activities produces complementary goods that are simultaneously assembled in a given proportion to form a complete product. If the demand for the product were known and the activities produced the goods at rates required for meeting this demand, there would be no management control problem. However, when demand is uncertain or the performances of the activities deviate from the set standards, or both, coordination of these activities may become an important problem. Optimal strategies for coordination would differ considerably according to whether or not surplus goods at any time could be stored for later use. This study investigates two cases, each with two parallel activities of uncertain performance and/or uncertain demand. In one case surplus goods can be in inventory, and in the other case they cannot. The uncertain demand or activity performance is assumed to change from one level to other levels with stationary transition probabilities. Optimal strategies are obtained by a stochastic linear programming method under the assumption of a Markovian steady state

TA5.10 Development and Application of a Class of Three Person Zero and Non-Zero Sum Game Theory Models with Insufficient Information, MICHAEL LIEBMAN, *Communications & Systems, Inc., George Washington University, Falls Church, Virginia.*

This paper is concerned with the treatment of a three person zero and non-zero sum game. The payoffs of the game are from two players to a third party where the parties which payoff to the third party receive secondary gains. These secondary gains will be the topic of concern in this paper as an attempt is made to maximize these secondary gains according to straight cost, utility, and cost benefit criteria. An additional factor will be the lack of knowledge on the part of the two giving players of what the other is going to give the third party. The problem will be illustrated by use of a hypothetical example.

TA5.11 A Methodology for the Use of Shadow Prices in the Parametric Analysis of Utility Payoffs in Game Theory, VICTOR SELMAN, *Communications & Systems, Incorporated, 6565 Arlington Boulevard, Falls Church, Virginia.*

One of the primary problems in the wide acceptance of the game theory concept as a decision-making tool is the subjectivity of the utility payoffs. The axioms and rules of von Neumann and Morgenstern concerning utility and value theory are well documented, in addition to the more recent works of Fishburn, Churchman, etc. However, the disagreement by the engineering community on the individual utilities for specific situations has hindered the progress of a wider application of game theory. In addition, the "balky" engineer forced into quantifying the utility of various outcomes under different environments would find it advantageous to know the parametric sensitivity of his numbers on the outcome of the ultimate decision. This paper investigates the use of linear programming shadow prices to determine the critical range and threshold values. It is shown how this

technique provides a better understanding of the range of utility and some advantages over previous methods in two person zero-sum games. An illustrated example is included.

TA6.1 A Systems Approach to Long Range Facilities Planning in Higher Education, THOMAS E. HOOVER, *The Ohio State University, Columbus, Ohio.*

With growing enrollment and expanding academic programs, the need for a quantitative method for developing long-range facilities plans and capital budgets has been made evident by management in institutions of higher education. The method requires construction of space-use models, by type of space, as a function of the user population and models for projecting the user population as a function of the gross population. User population projections, by year, are coupled with space models to estimate gross space needs. Net existing inventory and "in-process" inventory of space are subtracted from gross space needs to obtain the net space need, by year, by program. Variance in population growth is introduced to obtain a distribution of net space need. Within constraints provided by program affinities and combination of net space needs into feasible buildings, construction projects are selected. The selected projects are set up in a PERT network using normal event-time relationships and project precedence plus other precedence relationships established by management priorities and dollar-volume per year constraints. With the network, budget request and construction schedules are established which meet space needs by program for target planning years.

TA6.2 The Use of Micro-Structural Input-Output Systems Analysis in Educational Resource Allocation Decision-Making, RUSSELL C. KOZA, *Rensselaer Polytechnic Institute, Troy, New York.*

This paper describes the use of Input-Output Analysis as a technique for application to educational systems (college level) for description, analysis, projection, and control for purposes of resource allocation decision-making. A typical educational system is described through the use of an Input-Output inter-activity matrix and the concomitant primary and secondary resource inputs. The model developed is then used as a simulation device to exhibit the consequences of change in the total internal system structure by typical resource allocation criteria. In addition, the application of the developed technique to other types of systems is discussed and conceptual models presented.

TA6.3 A Projection Model for Higher Educational Systems Planning, RUSSELL C. KOZA, JOHN J. NEUHAUSER and ALLAN BAISUCK, *Rensselaer Research Corporation, Troy, New York.*

This paper presents a flow model of a state-wide higher educational system (college level) to be utilized for long-range planning and decision-making in New York State. The model describes the operational aspects of the educational structure permitting an examination of intersectoral flows for purposes of providing estimates of future demands upon selected sectors within the system. Use is made of regression techniques in determining the parameters of the model; and a Markovian approach for extending projections utilizes a high-speed large-core data processing

unit. The ultimate use of this simulation approach is to allow educational planners to estimate and anticipate the effects of social and economic change upon the flows within the system.

TA6.4 Establishing a Whole Blood Inventory Control System, C. CARL PEGELS, *Department of Management Science, State University of New York at Buffalo.*

Whole blood is a perishable commodity and has a very limited life span. In addition, blood donations are considered by many to be voluntary services which technically take human blood from the commodity classification into the service classification. Tradition and other constraints make it very difficult to impute costs to human blood, and hence a cost-related inventory control system is neither practical nor feasible. The usual commodity has an uncertain demand, but a certain supply. Human blood, on the other hand, has both an uncertain demand and an uncertain supply for each type of blood. There is some control on aggregate supply. Based on the above restrictions an inventory control system has been developed which determines required aggregate supply rates as a function of an allowable shortage probability β. The individual blood type shortage probabilities are adjustable within the allowable shortage probability.

TA6.5 Management Science as a Vehicle for Training and Evaluation of Japanese Middle Management, HERBERT GLAZER, *The American University, Washington, D.C.*

During the past two years the author has been involved in the development of a training program for Japanese middle managers of a foreign firm in Japan. The firm is an international conglomerate which markets its consumer and industrial products via agents in Japan. The head of the firm in Tokyo felt that it would be valuable for his middle managers to study management science in order to improve their ability and modernize their outlook toward managing their various product lines. What began as a lecture program evolved into a market research group headed by the author. The paper describes how concentration on the theoretical and exclusion of the practical in Japanese universities has prevented Japanese management from fully appreciating the role that management science can play in its own operations. As a result, it has been necessary in this firm to begin with simple marketing studies in order to involve the manager in some quantitative work with the eventual goal of leading him to more involved management science projects. By participating in these studies, the manager's understanding of his market can be evaluated.

TA6.6 A Model for Health Manpower Planning, E. NADDOR, L. SHUMAN and J. P. YOUNG, *Johns Hopkins University, Baltimore, Maryland.*

One of the most serious problems for the health services is the acquisition and allocation of appropriate manpower resources. Health planners, dealing with the system characterized by crucial shortages of skilled personnel, are faced with decisions related to the number and kinds of health manpower required to satisfy anticipated demands; and the extent to which technology and mechanization can

be expected to alleviate the situation. To this end, a parametric programming model has been developed that seeks to maximize the total units of "quality health services" that can be provided, given constraints on health funds available, predicted health needs, costs of acquisition and training, and maximum personnel and time available. The quality of services provided is assumed a value function of the personnel type giving the service (e.g., physician, nurse, technician), and the time devoted to each class of service (e.g., diagnosis, therapy, lab). Alternatively, the model can be used to minimize the costs of manpower resources required, given constraints on the total quality health services demanded, substitutability of personnel types and degree of mechanization. Results will be provided that show, for various methods of measuring quality of care and for various cost factors, the optimal mix and allocation of manpower.

TA6.7 Prediction of Consumer Demand for New Recreation Items, JOHN A. DIMLING, JR. and ROBERT A. PORTER, *Spindletop Research, Inc., Lexington, Kentucky.*

The desire to estimate the potential market for new products of a recreational nature leads immediately to the search for a consistent pattern of consumer behavior in purchasing such products. A consumer's decision to purchase recreation is limited (ultimately, at least) by the size of his income; historically, the average amount spent on recreation has been a relatively constant fraction of disposable personal income. Additionally, the total amount of *time* spent on recreation is limited by the other activities that are necessary in the consumer's life. The consumer must buy enough recreation to "fill up" his recreation hours, but he cannot spend more than a certain fraction of his time in recreation. The consumer's decision to purchase a particular recreation item must therefore take into account both an income constraint and a time constraint. Based on these two constraints, a theoretical model of the spending behavior of households is developed. The results of the model are found to agree quite well with the available empirical data. Experience with the application of the model to predicting the market for a new product is then described.

TA6.8 A Mathematical Model of a Ground Water Basin, STANLEY R. PLISKA, *TRW Systems, Redondo Beach, California.*

This paper presents a mathematical model of a ground water basin that simulates the basin's water level responses to alternative water inflow and outflow conditions. The flow of ground water can be described by a non-linear partial differential equation through the use of Darcy's Law and the law of Conservation of Mass. The model approximates the differential equation by finite difference equations through a subdivision of the basin and its hydrological history into nodes, paths, and time increments. The nodes correspond to data points at which some geologic and historic hydrologic information about the area is known. Polygons surrounding each node are constructed in accordance with the Thiessen method while constrained by the basin's boundary and fault characteristics. Integrals of subsurface, external and storage flows are approximated by a finite difference scheme using the polygonal space mesh and a suitable time mesh. The

solution of the system of difference equations for a nominal set of hydrological parameters is determined with a relaxation method. A correction process can be used to adjust the nominal parameters when historical water level data are available. The application of the model to a particular ground water basin is given.

TA6.9 Optimization of Water Quality Management, D. S. MILLER and W. L. MEIER, JR., *Texas A&M University, College Station, Texas.*

One of the most perplexing water pollution problems today is that concerned with how to insure optimal water quality management. For nonconservative pollutants within a river basin system, a complex interrelation exists between treatment prior to release to the stream, dilution of wastes by reservoir releases, and in-stream degradation. Previous research efforts have failed to include water quality control as a competing beneficial use of water in planning problems. Adequate consideration of pollution control within planning problems is necessitated by the fact that an estimated 100 billion dollars will be spent in the United States in the next three decades to maintain acceptable stream quality. In this paper a method for incorporating water quality management into the problem of planning for the optimal beneficial use of water resources is presented. Mathematical models of reservoirs, waste treatment facilities, and stream reaches are developed. A multistage optimization algorithm is developed, and solution of a typical example problem is given. Through the use of the multistage optimization algorithm, complicated water resource problems characteristically exhibiting a large number of decision variables and nonlinear utility functions are made tractable.

TA6.10 Disaggregative Measures in Validating Simulations of Social Science Phenomena, STANLEY F. STASCH, *Northwestern University, Chicago, Illinois.*

Simulations of the behavior of individuals in small groups or in relatively small social structures have been concerned primarily with aggregative measures. The validity of a simulation capable of duplicating observed results only at the aggregative level is questionable if other, differently structured simulations are also capable of duplicating the observed results at that same level. Because a number of differently structured simulations are frequently capable of duplicating observed aggregative results, serious questions can be raised concerning the level of and form of observed disaggregative behavior which must be duplicated by the simulation before placing confidence in its validity. Utilizing a computer based simulation, the author experimented with various levels and forms of disaggregative data to determine their usefulness in selecting the most valid of a number of alternatively structured simulations. The paper to be presented describes the computer simulation and the experimental design used in testing the utility of various disaggregative measures for validating simulations of social science phenomena. Some comments concerning the influence of chance and sample size (number of iterations) on the results will also be made. The social science phenomenon simulated was innovation diffusion through interpersonal influences.

TA6.11 Horizon Models for Social Development, A. CHARNES, S. C. LITTLECHILD and A. S. WALTERS, *Northwestern University, Evanston, Illinois,* and M. J. L. KIRBY, *Dalhousie University, Halifax, Nova Scotia, Canada.*

This paper discusses models for planning the social development of a country. One of the characteristics of these models is the way they include constraints and goals for planning the improvement in living conditions and the upgrading of different segments of society. The models also make extensive use of various sociological factors. While these models are presented in the context of a rapidly developing nation, the attributes they contain are not limited to such cases.

TP1.1 Integer Programming as a Sequential Decision Process, G. ANTHONY GORRY and JEREMY P. SHAPIRO, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

The scheme described in this paper applies sequential decision theoretic techniques to the solution of integer programming problems. An optimal linear programming basis is used to transform the problem into one for which an optimal correction of the non-basic variables is sought. The sequential decision process employs an implicit enumeration scheme which generates a sequence of partial solutions to the transformed problem. For various partial solutions, the process selects a computational alternative in keeping with the optimality criterion of minimal total expected cost to completion. A group theoretic view employed in the process promotes the integration of diverse computational alternatives such as branch and bound and cutting plane algorithms. Group theory is also the source of important insights into the structure of integer programming problems.

TP1.2 Exploitation of Solution Space Properties of Set Covering Problems, GARY M. ANDREW, T. R. HOFFMANN, *University of Minnesota, Minneapolis, Minnesota,* and C. B. KRABEK, *Control Data Corporation.*

Problems involving airline scheduling, truck routing, and assembly line balancing are often formulated as integer programming problems of the following form: minimize $\sum_{j=1}^{n} c_j x_j$ subject to

$$\sum_{j=1}^{n} a_{ij} x_j = 1 \qquad i = 1, 2 \cdots m \tag{1}$$

x_j's are zeros and ones, where all a_{ij} are either zero or one. All feasible integer solutions to the system of equations defined by (1) are such that the x_j's are either zero or one. Furthermore, all feasible integer solutions of this problem belong to the set of extreme point solutions of the constraint equations (1). The properties of integer solutions to the problem where equation (1) is of the form $\sum_{j=1}^{n} a_{ij} x_j \geqq 1$ are also investigated. (This is the generalized set covering problem.) The unique properties of the solution space are used to develop an algorithm for solving problems of the above class by modifying the simplex method. A sample problem is used to illustrate the method and computational experiences with the algorithm are presented.

TP1.3 Non-equilibrium Theory of Storage and Queueing Models, N. U. PRABHU, *Cornell University, Ithaca, New York.*

At the early stage of development of storage and queueing models, attention was mainly devoted to the investigation of their equilibrium (or steady state) behavior. Later contributions to the theory of these models have included the analysis of their time-dependent behavior. However, the results yielded by this analysis are complicated and are not considered suitable for practical use. It is therefore necessary to reconsider these results and seek meaningful approximations to them. The so-called 'heavy-traffic' theory of queues obtains approximations to the steady state distribution of waiting times under conditions where the system only just reaches equilibrium (specifically, where the relative traffic intensity is $\rho = 1 - \epsilon$, and $\epsilon \to 0 +$). In this paper we adopt a different point of view and obtain 'large time' approximations to the various distributions of interest in the case where the queuing or storage system does not attain equilibrium ($\rho \geqq 1$), in terms of standard probability distributions such as the normal.

TP1.4 Optimal Peak Inventory and Warehouse Capacity for a Seasonal Product, ANDRE C. DIMITRIADIS, *Trans World Airlines, Inc., 605 Third Ave., New York, New York.*

In this paper, one considers a product with a known production rate and a seasonal demand, whose inventory exhibits a cyclic pattern with one peak and one trough per cycle. Penalties are imposed when the product exceeds the capacity of its container or when it falls below a certain level. It is assumed that the seasonality exhibits a regular pattern so that the overflow can occur only around its peak and the underflow can only occur around its trough. The optimization is over one cycle and in the practical examples considered, the expected cycle length is one year. The inventory levels at the peak and the trough are expressed as random variables which are functions of demand, production, length of the season and the decision variables. The decision variables are the change in the production plan (leading to an optimal expected peak inventory), and the warehouse (container) capacity that will jointly minimize total costs. The total cost considered is made up of the inventory holding cost, the overflow cost, the underflow cost, the cost of warehouse capacity for the cycle and the cost of changing the existing production plan.

TP1.5 Determining the Economic Feasibility of Reliability Analysis, A. WILLIAM PERIGARD, *Grumman Aircraft Engineering Corporation, Bethpage, New York* and RAYMOND P. LUTZ, *New Mexico State University, University Park, New Mexico.*

A problem now facing the planners of long duration, manned space programs, is the formulation of meaningful maintenance schedules. Since these schedules are derived from data obtained through the use of some failure prediction method, the most accurate failure prediction method warranted by the mission economics should be used. The actuarial method of reliability analysis is more accurate than normal failure prediction methods when failures are dependent upon operational usage, but due to its cost, its use has been restricted to the analysis of jet

engine replacement. A mathematical model was developed to express the operational worth of a system as a function of both a system's criticality of usage and procurement cost and to verify that operational worth was the most meaningful indicator to use in prescribing a particular failure prediction method. A model was then introduced to evaluate any given reliability method of analysis. This produced an augmented cross-over chart which provided a direct comparison of the economic benefits to be derived from the use of either the actuarial or normal method of reliability analysis. This model would enable a decision maker to determine which type of reliability analysis would be economically appropriate once the operational worth of the system has been calculated.

TP1.6 An Inventory Model for Multi-Stage Production Processes, LAWRENCE ELLIOT SCHWARTZ, *Center for Naval Analyses of the University of Rochester, 1401 Wilson Blvd., Arlington, Virginia.*

Consider an m-stage production process, composed of m "shops" either in a mass production or a job shop context. Together these shops produce outputs composed of n parts. The model determines the optimal sizes of the n part and s semi-finished good inventories, where $s \neq n$ in general, which the shops should maintain. Also provided by the model are transfer prices so that rational tradeoffs can be made between inventories of spares and of semi-finished goods on the one hand and stocks of labor skills and capital on the other. The optimal inventory levels are found on a utility function criterion, which depends on the total cost of the entire production process. Included in total cost are such items as production costs; imputed demurrage charges for output held in the production process because parts of semi-finished goods are not available; the usual inventory costs; and the expected model computation costs. Both demands and costs are assumed stochastic. Optimization of the model is by dynamic programming, at each stage of which a sequence of decomposed nonlinear programming problems is solved.

TP1.7 Analysis of Capacity Utilization—A Bulk Commodity Vessel, GRANVILLE R. GARGIULO and STEPHEN B. ZIMMERMAN, *Arthur Andersen & Co., 80 Pine Street, New York, New York.*

Many U.S. firms importing large quantities of a single raw material commodity own and/or operate ships in order to service the requirements of their production facilities. The decision to purchase or build a vessel is normally based on a return on investment evaluation where the return is dependent upon the utilization of the ship's load capacity over each year's voyages. This paper describes a case study in which a company was planning to build a new, larger capacity vessel to transport a commodity from 3 supply ports to 4 plants. The objective was to determine an annual schedule of voyages that would most effectively utilize the available sailing days and maximize the difference between the going commercial rates and the lower cost of the company-operated vessel. In addition to the usual demand and supply limitations, several unique constraints were introduced to assure a realistic time-oriented schedule of voyages. Although some of the variables were restricted to integral values, the problem was solved as a continuous linear programming problem. The solution was then rounded to the nearest integers with negligible effect on the overall results and evaluation.

TP1.8 A Programming Approach to the Optimum Design of Multivariate Surveys, SAMPRIT CHATTERJEE, *New York University, 100 Trinity Place, New York.*

In this paper we present a programming approach to the sample size allocation problem. Formulation of an optimum sampling plan essentially involves a balance between cost and precision, the objective being either to attain maximum precision at a fixed cost or to attain a fixed precision at minimum cost. We take the latter approach here, and show that several schemes such as stratified sampling, two-stage sampling, etc. can be formulated as a non-linear programming problem. The solution of the non-linear programming problem determines the optimum sample size. We also present a method for guiding the sampler in his choice of tolerance levels. This is done by determining the cost implications of the tolerances. The price which the sampler is paying for each of the tolerances is obtained by solving the dual of the non-linear programming problem which determines the sample size allocation. An illustrative example is given.

TP1.9 A Maintenance Shop Simulator, JOHN A. BACHMANN, *Virginia Polytechnic Institute, Blacksburg, Virginia.*

A GPSS simulation of a day-shift maintenance shop in a continuously operating synthetic fibers plant is described. It is used as the model for a competitive non-interaction operating policy management game. The plant has a fixed number of spinning positions which must be kept operating. The workers in this maintenance shop only repair the winding machines which are one of the critical parts of each position. Waste is produced if a machine fails and there is no available spare. Failures are random during a week, and there are major and minor categories of repairs. Overtime call-ins occur when the number of available spares fall below a critical level.

TP1.10 Internal Determinants of Capital Structure, EAMON M. KELLY and EUGENE R. MELANDER, *The Pennsylvania State University, University Park, Pennsylvania.*

The cost of capital and its determinants have been the concern of several significant studies recently in finance. One of the more critical variables in the analyses of cost of capital, the firm's capital structure, is investigated in this study. Adopting the Myron Gordon thesis that businessmen view capital structure as a constraint on their investment behavior, the study posits that capital structure is a function of anticipations with respect to the following variables: profits, growth, stability, and liquidity. Various definitions of the variables—both dependent and explanatory—are considered in alternative formulations of the general model. The primary objective of the study is the specification and identification of a "sub-optimizing" model demonstrating the basic determinants of the capital structure constraint. In addition, cyclical and structural changes in the determination of capital structure are tested. Data from the Standard and Poor Industrial Compustat Tape are utilized to obtain through statistical analyses, primarily regression analyses, the most significant set of determining factors of capital structure and estimates of their parameters.

TP1.11 A Model for Allocating Interceptors with Overlapping Batteries: A Method of Nonlinear Programming, B. J. DUNN, P. H. RANDOLPH, G. E. SWINSON, M. E. WALKER, *Braddock, Dunn and McDonald, Inc., El Paso, Texas* and R. D. WILLIAMS, *Sentinel System Evaluation Agency, White Sands Missile Range, New Mexico.*

A nonlinear programming method is developed for the optimum allocation of a fixed stockpile of resources. The method lends itself to problems whose physical characteristics are completely general in nature. The method of successive approximation in dynamic programming serves as a format for the computational scheme. This scheme leads to a relative optimum solution in general and to an absolute optimum in certain instances. The initial "policy space" estimate determines whether the solution converges to a relative optimum or to absolute optimum. By choosing starting points at random, a distribution of relative optima are generated, on which optimal stopping rules are applied. The experimental results to date indicate that the computational technique is stable regardless of the degree of optimality the solution possesses. The computational efficiency of the method has exceeded expectation. Available computing hardware serves as the only restriction upon the complexity of problems which may be solved by this technique.

TP1.12 A Generalized Weapon Allocation Game, JOHN D. MATHESON, *Analytic Services Inc., Falls Church, Virginia.*

This paper discusses solutions of a generalized two-person game involving the allocation of attacking and defending weapons to a number of targets with differing characteristics. For each type of target, the damage function is a matrix of expected target value surviving as a function of integral numbers of weapons. The solution strategies for any given force sizes are associated with a kernel matrix composed of elements from the proper rows and columns of the several damage function matrices. With the solution kernel known, the precise solution strategies and the value of the game can be computed from the equality conditions of game theory by matrix inversion. The solution process begins on a known kernel, commonly where the force sizes are zero, and then varies the force sizes over any prescribed rectangular path. Critical force sizes, and the kernel changes associated with them, are found by means of the inequality conditions of game theory. A simple computer program carries out the solution process and generates a complete spectrum of solution strategies and values of the game along the prescribed path. The program is flexible and can be specialized in a variety of ways for particular applications.

TP1.13 The Role of the Scenario in Current Military System Procurement, RICHARD F. POPPE, *The Boeing Company, Missile and Information Systems Division, Seattle, Washington.*

The scenario has proven to be a preferred alternative to the arbitrary specification of military system requirements and effectiveness criteria. The trend toward scenarios is described using recent concept formulation and contract definition studies as references. A proper scenario provides the background for the re-

quired operations research, analysis and system synthesis tasks. The total military and geopolitical environment must be specified at the proper intensity level and with the proper initial conditions. Such an approach is a valuable aid to the analyst who must define the measures of effectiveness at the correct levels, fix the "imponderables," provide a common base to compare competitive proposals and finally to assure that the resulting analyses may be integrated into a DOD-wide comparison of alternative approaches to satisfy the military need. The contractor's system synthesis may then determine the operational and technical system requirements in more nearly optimal fashion. A detailed description is provided of the desirable scenario characteristics along with examples of what a scenario should and should not attempt to accomplish. A discussion of the relative merits of static, dynamic and hybrid types of scenarios and their impact on the analysis workload is presented.

TP1.14 Highway Congestion-Evaluating Urban Highway Improvement Alternatives, JOHN L. SCHLAEFLI, *Stanford Research Institute, Menlo Park, California.*

Results of Institute and U.S. Department of Transportation sponsored research in the field of urban highway congestion is discussed. A computer model of the dynamics of traffic flow on an urban road network has been developed for comparing alternative schemes of traffic congestion relief. The user service characteristics of these improvements together with their associated costs can be used by the decision maker in setting the highway budget and allocating it to the most cost-effective projects. The model has been programmed and its economic and technical feasibility demonstrated. Of utmost importance to future application of the model is verification of the assumptions upon which it is based. This empirical verification phase has been in progress for approximately one year. The test network consists of a seven square mile section of the city of San Francisco that is being examined during the morning rush hour. This section of the city has about 350 arterial links, about 100 signalized intersections, and accommodates approximately 70,000 automobile trips during the morning rush hour. From results of the study to date it would appear economically and technically feasible to compare all alternative highway improvements on a user service basis. Further, substantial improvements in urban mobility may be achieved by relatively low cost regulatory or control techniques.

TP1.15 Operations Research Applications in Forest Fire Management Systems, FREDERICK W. BRATTEN and JAMES B. DAVIS, *Forest Fire Laboratory, P. O. Box 5007, Riverside, California.*

Forest fire suppression forces may build up, within a few days, to levels of hundreds or thousands of men, machines and aircraft on a major fire. The problems of efficiently mobilizing, directing, and maintaining such forces, often under difficult environmental conditions, are challenging indeed. Operations research techniques are finding increasing use in attacking some of these problems. The U. S.Forest Service Forest Fire Laboratory at Riverside, California has a small O.R. group working in this area. At present, work is concentrated on exploration

of the use of on-site or remotely linked ADP equipment to aid in solving some of the on-line fire management problems. A data storage and retrieval system for fire environment (INFORMAP) is in a preliminary development stage. Other computerized aids being studied are an optimizing initial attack force dispatching model, a fire suppression resource allocation model, and a stochastic fire spread simulation model.

TP1.16 Operations Research in Outdoor Recreation, FRANK J. CESARIO, *Battelle Memorial Institute, Columbus, Ohio.*

Outdoor recreation has overtaken baseball as America's national pastime. Participation in outdoor recreation activities has tripled since World War II and is projected to rise another 3 times by the year 2000. This increased use pressure on our recreational resources has forced all levels of government to employ more primary factors of production in acquiring, developing, and maintaining the supply of recreation resources to withstand and keep ahead of the increasing demand. Only within the last 3 years have analysts been actively engaged in developing and applying the quantitative techniques of operations research to achieve an efficient allocation of resources to recreation. This paper traces the development of operations research and systems analysis in outdoor recreation and presents some future areas of research and possible ways of going about it. The main points of discussion will include (a) techniques for estimating the economic benefits of outdoor recreation, and (b) methods of estimating recreational travel flow.

TP1.17 Outline for Scientific Attack on Some Urban Problems, OSCAR PERILLA, *The Port of New York Authority, 111 Eighth Ave., New York, New York.*

This paper presents an abstraction of the urban system with man as its basic building unit. The abstraction retains the characteristics of people that seem to motivate human behavior in an urban setting. It states some of the basic principles that appear to underlie and limit this behavior and outlines the consequences on urban growth and structure that follows from these principles and characteristics. It also reviews some empirical work that indicates the approach is useful to clarify structural relationships in the system, and the effects of some individual, community and institutional goals on its development. The approach is also useful to identify interfaces in the system where the contributions from several disciplines are needed to complete basic understanding of its structure and function.

TP1.18 Decision Problems and the Control of Economic Processes, KARL BORCH, *The Norwegian School of Economics and Business Administration, Bergen, Norway.*

In the classical theory of investment one compares "cash flows" by comparing their present value. The decision rule then consists in selecting the cash flow with the greatest present value. The interest rate used in the process represents the subjective element in the decision. If a choice has to be made among investments giving returns represented by stochastic variables, one can compare different investments by computing their expected utility. The decision rule will then consist in selecting the investment which has the greatest expected utility, and the utility function represents the subjective element in the decision. The

natural generalization of these two classical problems is to assume that an investment gives a sequence of stochastic payments. The problem is then to find a decision rule, depending on a preference ordering over a set of stochastic processes. This is not a simple problem, and it becomes even more complicated if the decision maker has some opportunities of correcting his choice at some future points of time. These problems are discussed in the paper, with particular reference to management of a firm, and of a portfolio of securities.

TP1.19 Integrating Computers into a Functioning Business Structure
HARRY A. STERN, *General Foods Corporation, White Plains, New York.*

Information systems should be designed as an integral part of a business, and not superimposed upon it. Too often computer systems have been built to replace manual and card systems, and justified on the basis of projected clerical or machine savings, which almost never materialize. In truth, a company must change its way of doing business if it is to take significant advantage of computers. Because any significant application of computers must involve dramatic change, it behooves management to understand the nature of these changes. Once management has grasped this, it can guide the development of computer systems in such a way that it coincides with other changes taking place within the business. This paper discusses the uses of information systems in industry and possible ways to better them. It treats three topics: the technical use of computers and languages, the intellectual difficulties in applying computers, and the changes which make it possible to apply computers in specific areas.

TP1.20 Policy Decisions can be Automated, JOHN LASTAVICA, *The First National Bank of Boston, 67 Milk Street, Boston, Massachusetts.*

Management Information System should be a management tool. Information for top management is one of the primary objectives in the development of a Total System, a system which provides automated abstraction of all the information contained in data banks. The current debate on Total Systems often presents ideas to top management from the narrow viewpoint of computer technicians, whose main concern seems to be the ability to manipulate vast amounts of data. Consequently, noncomputer oriented corporate managers have been reluctant to move towards Total Systems. In order to overcome this difficulty, it is proposed that the advantages and benefits from Total Systems be explained in the framework of Corporate Management thinking. The problem areas, present and potential, should be defined and then the decision model should be selected, be it a sales analysis schedule or a mathematical model. Finally, the method of extracting data appropriate for the decision should be determined. In proceeding with a System design in this fashion, Corporate Planning into the future will be made positive, and advantages will accrue, well in advance of implementation. A by-product of this philosophy may be an economical real-time computer system, which would provide information for policy decision making instantaneously available in Corporate board rooms.

TP1.21 Divisional Planning and Control Systems: A New Proposal, ALFRED RAPPAPORT, *Northwestern University, Evanston, Illinois.*

The disparity between discounted cash-flow capital investment planning models and divisional control models based upon accounting return-on-investment measurements, suggests a compelling need for a new approach to divisonal planning and control among organizations with decentralized profit responsibility. The importance of this problem is underscored by the observation that conventional control models are often used as a basis for (1) executive promotion and compensation; (2) decisions involving allocation of scarce funds among divisions; and (3) a purposeful strategy of suboptimization by divisional executives. The proposed planning and control system purports to: (1) provide decision-making guidance and positive motivation to divisional executives; (2) measure the productivity of capital invested in the division; and (3) serve as a basis for evaluating the performance of divisional executives.

TP1.22 A Combination Bayesian—Programming Approach to New Product Selection, D. G. FREDERICK and D. J. LAUGHHUNN, *Department of Marketing, University of Illinois, Urbana, Illinois.*

This paper develops a systematic model for selecting new product proposals which evaluates decisions for all proposals simultaneously over a multi-period planning horizon. The model allows for sequential examination of each product through the successive stages of its development prior to market introduction. The decision options at each stage of evaluation for each product are to drop the product from further consideration or to enter the next stage of product development. Further, if the decision is to enter the next stage of product development, an optimal experiment is designed to gather additional information for the product prior to the next decision point. Specifically, at each decision point expected net present value is determined for each product proposal by performing Monte Carlo analysis on the multivariate distribution of variables that determine payoff. A mixed integer linear program is then used to select an optimal set of proposals from the total set subject to all relevant restrictions. The risk of classification into optimal and non-optimal sets is then examined by discriminant analysis. For these proposals in the accepted set, Bayesian preposterior analysis is utilized to determine optimal experiments on relevant variables during each stage, and experimental information is then combined with prior estimates using Bayesian methods at the next decision point. The entire procedure is repeated at each decision point, thus permitting a re-evaluation of the decision to drop, commercialize, or continue a given set of product proposals through the research and development process.

TP1.23 Integrated Systems Planning for the Implementation of Planned Socio-Economic (Agricultural, Industrial, and Social) Development in Developing Countries, using Network Analysis, EUSTACE P. C. FERNANDO, *United Nations Development Programme, 204 Buller's Road, Colombo, Ceylon.*

Any planned development programme could be provided with a compatible operational implementation strategy and plan, whose basic elements are outlined. Seven criteria for evaluating "Implementability" are proposed. Identifying and dealing with inter-temporal interdependencies relating to the diverse activity and resource requirements constitute the essence of the problem. An integrated agro-

industrial development programme illustrates the key role that network analysis could play in resolving this problem. A "Project-sectoral interdependency matrix" is set up, triangulated, and then transformed into a network. The matrix and the network are then used to analyze implementability and alternative implementation strategies by applying all the generally applicable network analysis theory. Thereby, the appropriate implementation strategy and plan is evolved. Programming for coordinating all the supporting sectors of the economy in the implementation is illustrated conceptually. The more realistic projection of all activities and resources is derived as flowing from the final time-oriented implementation network thus evolved. Ten other implications to implementation strategy and systems are also summarized. The application of other Management Science principles and Operations Research techniques also emerges in the exercise. The indigenous development of implementation systems technology is urged as the means of systematically closing the chronic "Implementation gap" that confronts developing countries.

TP1.24 The Manager Chooses Between/Among Alternatives: Game-Theoretic Approach, JEROME H. N. SELMAN, *Stevens Institute of Technology, Hoboken, New Jersey, and U. S. Army Munitions Command, Dover, N. J.*

Ever larger and more complex systems provide management with more and more exotic artificial sensors, with instant communication linkages to bring information quickly within ken, with unexcelled display, computer and storage facilities to retrieve information quickly and accurately, even reminding the manager should he forget. But modern technology has provided the manager with little help to assist him in figuring out what all the information means, to help him assimilate and use the available information. The tool that the manager uses to interpret the mass of information is precisely the same tool of training and experience that Alexander the Great used to make his decisions. Managers are not convinced that the complexity of the problems makes them incomprehensible to a single human being unless he utilizes the tools of management science *with* his intuition and "gut" feeling. Thus the management solution of the multidimensional value problem resolves itself into two tasks. One task is the subjective evaluation of each possible combination of act/state on each of the value dimensions, considered separately. The other task is to combine, or synthesize, these judgments about the separate value dimensions into a single payoff matrix. The manager himself must perform the first task—inescapably one of subjectivity and human value judgments. The manager may mechanize the second task by heuristic decision rules; modern Game Theory is proposed as the solution to this moiety of the decision problem, with the decision domain between the Charybdis of the tidy zero-sum game and the Scylla of the not-so-tidy non-zero-sum game. The audience will participate in determining their own utility functions for various parameters in military and industrial payoff matrices, and decide the "better" of two alternatives via game-theoretic solution concepts.

TP1.25 Water Resource Development and Management in the Tucson Basin, CHESTER C. KISIEL and LUCIEN DUCKSTEIN, *University of Arizona, Tucson, Arizona.*

The development and management of water resources in a well defined basin is considered; the Tucson (Arizona) basin is used as a focal point of the pilot study. The problems encountered involve a combination of social, political, economic and technical factors and can be classified into three broad categories: (1) modeling and analysis of the hydrology of a closed basin in the face of limited data; determination of additional data needs for efficient modeling and future management, (2) efficient allocation within the framework of legal and institutional constraints on limited ground and surface water resources, (3) determination and evaluation of various alternatives for water conservation and importation. A conceptual model of the system serves as a basis to define a series of new suboptimization problems in this subject area; in particular, those of replacement (well systems), scheduling, sequential decisions and quality control, among others. In this framework, the input set, state set and possible output functions are identified on a geographic grid wherein the feasible combinations of variables for combined surface and ground water management (reservoirs, wells, reclamation, laws, institutions) are specified. The above results precede simulation of basic political interactions associated with multiple purpose ground and surface water resource development and management.

TP1.26 A Model for Response to Multiple Profit Incentives, DAVID E. VAN TIJN, *Computer Applications Incorporated, Huntsville, Alabama.*

A model is developed for the response of an organization to profit-incentives involving a threshold function and a forcing function. Action to optimize profits would be taken when the forcing function exceeds the threshold function. Very weak assumptions on these functions are sufficient to derive certain optimality conditions on the incentive structure. The problem of confirming the existence of the functions is explored.

TP1.27 Investigation of the Decision Making System in a Large Single Enterprise—Some Theoretical Aspects, R. BANDYOPADHYAY, *University of Strathclyde, Glasgow C-1, Scotland.*

After reviewing the existing literature on the subject, the paper puts forward some of the more intricate problems faced in attempting to investigate the decision making system in a large single enterprise. It then attempts to introduce certain devices and concepts by means of which these difficulties can be obviated. Further, problems of evaluation of decision and information systems are fully discussed and a theoretical model for dynamic decision making is built up.

TP1.28 The Impact of Technology on the Mental Content of Industrial Operations, JOHN P. VAN GIGCH, *Oregon State University, Corvallis, Oregon.*

Information Theory is used to study and measure the mental load of operators employed in industrial jobs. Methodology to study mental effort is developed to complement traditional work measurement techniques of studying physical work. The average information processing rates of industrial operators employed in a process found at different levels of technology are measured. Comparisons include the analysis of the mental load of a process control operator before and after

the installation of a computer. Results lead to the evaluation of the capacity of the human communication channel to cope with the demands of increasing equipment complexity. Implications regarding the training of workers slated for the jobs created by new technology and implications regarding other manpower skill requirements are drawn.

TP1.29 Allocation of Research Funds, GLEASON A. BRANCH, JOHN PESCHON, ANDREW J. KORSAK and LEWIS MEIER III, *Stanford Research Institute, Menlo Park, California.*

The objective of the work described is to establish a methodology for allocating a fixed research budget to maximize the expected benefit derived. Applied research is viewed as a mechanism to increase the performance of a system as a consequence of improved operation, relaxation of constraints, or reduction of environmental uncertainties. The word "system" in this context is interpreted broadly; the systems considered may range from the financial performance of a business undertaking to the guidance accuracy of a missile system. The methodology is logically divided into three steps, namely establishment of performance sensitivities with respect to improved operation, relaxation of constraints, and reduction in uncertainty, that would be the result if an R and D project were initiated; secondly, modeling of the relation between these results and the R and D funds spent; thirdly, selection of that R and D alternative or combination thereof that maximizes the expected performance improvement subject to given budget constraints. The main analytical techniques used to implement the methodology are nonlinear programming, estimation theory, and information value theory. Although the current methodology is directed toward research in missile guidance systems, the fundamental logic and computer programs employed here are equally useful for more general applications.

TP1.30 Sequence Effectiveness Estimation, F. H. KRANZ and C. H. FRITZ, *North American Aviation, Inc., Downey, California.*

Management's need for a workable method of estimating the effectiveness of operational sequences of manufacturing, fabrication, assembly, testing, or a combination of operations, has increased as rapidly as product and operational complexities have increased. While it is true that useful effectiveness evaluation methodologies based upon the queuing theory, critical-path sequencing, stochastic programming, and other analytic techniques have been developed, many are difficult and expensive to apply. Others are mathematically feasible, but are not designed to produce workable answers to in-the-field operational problems. This paper describes a relatively simple methodology which has proved useful not only for formulating an estimate of the effectiveness of a sequence, but also for verifying the desirability of changes through use of the estimate formulated. This paper illustrates the estimation method by use of an example. It is a hardware-oriented approach to effectiveness evaluation and includes use of the processing sequence plan, equipment-failure rates, equipment operating time, standby time, available time for repair, repair time, and spares available. The process described involves determining what failures can be repaired in the time available for repair, and evaluating the probability of occurrence of no failures and repairable failures.

Management decisions, including those affecting spares policy, hardware design, and the sequence process, have been satisfactorily effected by use of this evaluation method.

TP1.31 Time-Sharing Computers as a Means for Bringing Modern Practices to Small Banks and Small Communities, H. CLAY SIMPSON, JR., STEPHEN L. WHITMAN and RICHARD S. BOWER, *The Amos Tuck School of Business Administration, Dartmouth College, Hanover, New Hampshire.*

Small communities and small banks, like other small institutions, often find it difficult to take advantage of modern management techniques because they lack properly trained personnel and adequate computer facilities. With the computer power, user-oriented languages and conversational mode programs available from time-sharing computer facilities these difficulties can be overcome. This is being demonstrated in small New Hampshire communities and small New Hampshire banks which have remote terminals on line to a General Electric computer. Planners in the communities and officers of the bank have been provided with an introduction to time-sharing and computer programming and are now utilizing, learning from and modifying computer programs that incorporate a variety of operations research techniques. In programs used by community planners, relevant relationships are derived from stored data and the user interacts with the computer in adjusting these relationships until they seem consistent and adequate for projections In budgeting teachers' salaries, for example, school census data are analyzed, student-teacher ratios are considered, salary increments are estimated and the sensitivity of future expenditures to alternative decisions is shown in sets of summary figures. In the bank, programs are now in operation which account for installment loans, simulate the effects of management decisions on projected operating statements, use exponential smoothing to forecast deposits and employ linear programming to test the impact of various constraints on bank asset portfolio. In our demonstration, interested attendees at the meeting will be able to see these programs in action and experiment with them on a teletype terminal connected through a telephone outlet to the General Electric 635 computer.

TP2 Panel on: Systems Analysis in State and Local Governments, CHAIRMAN: HARRY P. HATRY, *George Washington University, Washington, D.C. 20036.*

The panelists will discuss the applicability and potential of systems analysis/cost-effectiveness concepts to assist in state and local government program planning. The emphasis will be upon efforts undertaken by personnel *within* state and local governments rather than on ad hoc studies performed by contractors for them. The panel participants will report on work currently underway in governments throughout the country and will attempt to assess the potential impact of this work on governmental decisions. Current demonstration projects, including the Ford Foundation sponsored "5-5-5" project and the HUD-ICMA-NBS "Local Government Systems Analysis" project will be covered. As the application of systematic analysis to program planning is essentially a new thrust for state and local governments, the findings and views of the panel will necessarily be preliminary. The session will focus upon applications rather than methodology.

TP3.1 *Operations Research at COMSAT, J. H. ENGEL, *Communications Satellite Corporation, Washington, D.C.*

COMSAT is a unique enterprise. It is a privately owned United States corporation operated for profit and created by Act of Congress. It is the United States entity for participation in commercial communications by means of satellites. It is a regulated public utility. It is a partner in an international venture to provide commercial communications through the use of satellites to the nations of the world on a global and non-discriminatory basis. It is the manager for the international consortium of the space segment of the global commercial communications satellite system. As a new type of entity utilizing the new technology associated with satellite communications, it presents many new problems to its management. COMSAT is endeavoring to utilize the most modern and effective tools to assist its management decision makers. Operations research and systems analysis are used to illuminate a variety of topics in ways which will be described. These include: 1. Determination of optimum technical characteristics for space and ground segments. 2. Optimizing of operating procedures. 3. Traffic analysis. 4. Revenue requirement analysis. 5. The interaction of satellite communications with other existing and contemplated communications systems. 6. The development of computer assisted planning tools, such as models of corporate activity.

TP3.2 *Computer Assisted Resource Allocation for Satellite Systems
R. D. MARSHALL, *System Development Corporation, Santa Monica, California.*

A computer assisted work scheduling and resource allocation system has been developed for the Air Force Satellite Control Facility. The system provides access to a data base containing information on satellite positions, tracking station equipment availability, satellite service requirements, etc. via an interactive CRT display utilizing a function keyboard, typewriter, and light pen. Priority algorithms can be inserted into the program for automatic conflict resolutions, or the conflicts can be manually resolved utilizing displays and hard copy printout generated by the system.

TP3.3 Panel on: Operations Research Applications in Space, CHAIRMAN R. J. FREEMAN, *General Electric Center for Advanced Studies, Santa Barbara, California.*

The panel will discuss operations research studies in the space area. Applicability of various operations research techniques to space problems will be considered. Future potential contributions of operation research of the U. S. space program will be analyzed.

TP4 Panel on: Education in Military Operations Research, CHAIRMAN J. R. BORSTING, *Naval Postgraduate School, Monterey, California.*

This panel will consider some of the problems associated with education for operations research analysts working on military problems. The training and development of operations research analysts is a problem of continuing interest to government and industrial organizations. The educational requirements for analysts, at both field and pentagon levels, will be presented. Based on the requirements stated, suggested approaches for providing improved education for

prospective operations research analysts will be discussed. The discussion will include the requirements and educational programs for both military and civilian analysts.

TP5.1 *A Research Program on the Management of Research and Development, BURTON V. DEAN, *Case Western Reserve University, Cleveland, Ohio.*

In recent years the scientific study of the nature of research, the organizational structure of science and the management of research has had increasing attention. The impetus has come from (1) needs for public accounting of the expenditures on research and development and related activities, (2) the industrial benefits from applications of science and technology, (3) long-term incentives within the various academic and engineering fields related to research management, and (4) a growing realization within the physical and engineering sciences that the management of science and engineering is essential to the progress of the disciplines. The essential concept of the program for research on research management combines elements of the social, behavioral and management sciences in a systems approach to managerial decision problem formulation and solution. The elements of this system are the major organizational elements in our society that are affected by scientific and technological innovation. The systems approach provides the means for measuring flows and interactions as well as for raising meaningful research questions. The nature of research, the organization and structure of science and technology, and the research management processes are central topics of the study. In this study thirteen related projects undertake, on an interdisciplinary basis, to analyze nine decision problems. The chief disciplines involved are operations research, economics, history, political science and sociology.

TP5.2 *Theoretical and Computational Analysis of R and D Project Utility Ranking Models, JOHN R. MOORE, JR., and NORMAN R. BAKER, *Purdue University, Lafayette, Indiana.*

Several authors have proposed using project utility ranking models for prescriptive analysis of the R and D project selection decision problem. Recent research indicates that these models meet with neither theoretical nor important practical requirements. For example, many authors recommend a multiplicative index, over an additive index, in order to generate a wide range of project scores. The multiplicative index is shown to be a theoretically invalid utility measure; whereas, the additive index is valid. The most serious shortcoming, however, is the relatively arbitrary fashion in which the models have been constructed and the failure of the model builders to recognize the impact of certain structural considerations on resulting project scores. Extensive computational and parametric analysis demonstrates that the performance of a ranking model is highly sensitive to decisions made during the development of the model. Considerations such as (1) the underlying distributions of project data, (2) time preferences, (3) the number of ranking intervals or categories, and (4) the width of the intervals, all have important implications for final project scores and associated rankings.

TP5.3 *Exploratory NBS Studies of Benefit Cost Measurement in Research and Development, JOHN T. YATES, JR., HOWARD E. MORGAN and R. D. HUNTOON, *National Bureau of Standards, Gaithersburg, Maryland.*

An exploratory benefit cost study was carried out on seven National Bureau of Standards' research projects concerned with the improvement of scientific measurement techniques. Methods appropriate for each project were developed for the estimation of the primary economic benefit of the project. A summary will be given of the methods devised and of the results obtained. A critical analysis of the meaning of the results will be presented.

TP5.4 *Studies of the Interface between Research and Development and Related Activities, ALBERT H. RUBENSTEIN, *Northwestern University, Evanston, Illinois.*

A number of related, but independent studies have been conducted at Northwestern over the past few years in the general area of: interface, liaison, technology transfer, and diffusion of research results. The results of some of these studies are discussed and several models for describing and predicting the various aspects of this process are presented.

TP6.1 All Integer Integer Programming Algorithm, GORDON H. BRADLEY, *Stanford University, Stanford, California.*

A new all integer integer programming algorithm is developed that utilizes a little known theorem of Hilbert on diaphantine inequalities (extended and proven constructively by Thurber). The Hilbert result enables any integer programming problem to be reduced to a series of knapsack problems. The knapsack problems have, in general, more variables than the original problem. The algorithm works with only those constraints that are necessary to assure that the optimal solution is obtained. The algorithm is shown to have fewer iterations than the number of constraints. Computational results are discussed.

TP6.2 Towards an Unifying Theory for Integer Linear Programming, STANLEY ZIONTS, *State University of New York at Buffalo, Buffalo, New York.*

During the last decade a great number of approaches and even more schemes have been proposed for solving integer linear programming problems. These range from the implicit enumeration schemes including, for example, the additive algorithm of E. Balas to schemes that proceed in a simplical fashion to an optimal solution as does, for example, the All-Integer Method of R. Gomory. Still other approaches have been heuristic in nature and strive to achieve so-called good (not necessarily optimal) solutions. The purpose of this paper is to discuss a framework that appears to offer some potential for devising new algorithms, and, at the same time, provides a theory that helps to unify some of the previously advanced methods for solving integer linear programming problems. The framework involves the use of bounds on variables and is related to some of the author's earlier work on the Geometric Definition Method of Linear Programming.

TP6.3 Comparison of Integer Programming Algorithms, G. S. DAWKINS, *University of Houston, Houston, Texas,* and W. J. MEARS, *McDonnell Automation Company.*

A number of Integer Programming algorithms are currently available. A series of forty integer programming test problems have been solved using six non-proprietary algorithms based on cutting-plane constraints—one algorithm is based on a

direct tree search method, and one algorithm uses a branch and bound technique. The efficiencies of the different integer programming codes will be compared for different types of test problems.

TP6.4 Stochastic Programming With Separable Recourse Functions, M. AVRIEL and A. C. WILLIAMS, *Mobil Research and Development Corporation, Princeton, New Jersey.*

This work deals with activity analysis models represented by a linear program in which the right-hand side is a random variable. In this model, the decision maker chooses the activity levels first which leads to some production position and profit. Next, the actual value of the supply/demand vector is revealed and then some corrective actions are taken to resolve the differences between the production positions and the actual values of the supply/demand vector. The costs of, or the revenues from these actions are functions (the recourse functions) of these differences alone. The objective is to choose the activity levels so as to maximize the overall expected profit. First, some previous results obtained for the linear recourse model are briefly reviewed, then a model with a general separable concave recourse function is introduced. This model is analyzed by applying the conjugate function theory to obtain duality relations which in turn yield existence and characterization theorems for the optimal solution. In addition, we obtain several error bounds for estimating the amount by which we fall short of optimum when solutions of an ordinary linear program (with arbitrary fixed right-hand sides) are obtained. Finally, the results of this work are illustrated by a simple stochastic model with inventory capabilities.

TP6.5 Application of Rejection Region Theory to the Solution and Analysis of Two-Stage Chance-Constrained Programming Problems, WILLIAM M. RAIKE, *University of Texas, Austin, Texas.*

The theory of rejection and acceptance regions for chance constraints can provide important qualitative information regarding (not necessarily linear) chance-constrained programming problems with general classes of decision rules, as well as permit explicit solutions in a number of interesting special cases. We herein examine certain two-stage models having conditional and total-probability chance constraints from the viewpoint of the theory of rejection regions and derive deterministic equivalents not previously available for such models.

TP6.6 Time Delay in Minimax Optimization of Unimodal Functions of One Variable, JOHN H. BEAMER and D. J. WILDE, *Department of Chemical Engineering, Stanford University, Stanford, California.*

A minimax search plan is developed for locating the maximum of a one-dimensional unimodal function when a time delay occurs between the placement of an experiment and the result. The optimal search plans, among all the plans which place only one experiment at each unit of time, are determined for time delays of one and two periods. These plans are optimal in the sense that for a required final interval of uncertainty, they have the largest possible starting interval. Discrete variable (lattice) versions of these plans are also given, as well as plans for when the number of experiments is unknown initially. When more than one

experiment can be made at each unit of time, a variant of block search is more efficient.

TP6.7 Necessary Conditions for a Local Optimum Without a priori Constraint Qualification, G. REKLAITIS and D. J. WILDE, *Department of Chemical Engineering, Stanford University, Stanford, California.*

Necessary conditions for constrained optima which are independent of the Kuhn-Tucker Constraint Qualification are derived. The discriminating criteria are quantities directly computable by elementary matrix manipulations on the Jacobian matrix of the constraints. In contrast to the familiar complementary slackness between constraint and multiplier, the conditions involve sign complementarity between, on the one hand, constrained derivatives of certain constraints and, on the other, constrained derivatives of the objective function. Two necessary conditions are presented: one first order, requiring continuous differentiability of constraint and objective functions; the second, and stronger, requiring twice continuous differentiability of the constraints. Since the criteria are entirely computable, no formal a priori constraint qualification is required.

TP6.8 A Partitioning Algorithm for Structured Linear Programming Problems, DAVID WEBBER, *IBM Corporation, White Plains, New York,* and WILLIAM W. WHITE, *IBM Corporation, 590 Madison Ave., New York, New York.*

An algorithm for solving linear programs is described, where the coefficient matrix of the linear program has the following structure: blocks of coefficients along the main diagonal, over-all linking constraints, and over-all linking activities, with the rest of the coefficient matrix being zero. The algorithm is based on a partitioning approach using the simplex method, as opposed to a decomposition approach, and intermediate solutions are primal feasible. Similarities to and differences from other partitioning algorithms will be noted. Problems of the implementation of such an algorithm will be discussed, including the introduction and effect of some strategic considerations on convergence. Through an experimental program implementing this algorithm and various specializations, it is hoped that more insight will be gained into the behavior of partitioning approaches as methods for solving structured linear programming problems, and large scale structured problems in particular.

TP6.9 Mathematical Programming with Increasing Constraint Functions, WILLIAM P. PIERSKALLA, *Case Western Reserve University, Cleveland, Ohio.*

The mathematical programming problem—find a non-negative n-vector x which maximizes $f(x)$ subject to the constraints $g^i(x) \geqq 0$, $i = 1, \cdots, m$—is investigated where $f(x)$ is assumed to be concave or pseudo-concave and the $g^i(x)$ are monotonic increasing functions. It is shown that under certain conditions on $g^i(x)$, the Kuhn-Tucker-Lagrange conditions are necessary and sufficient for the optimality of x^*. It is also shown that the $g^i(x)$ are a useful class of functions since, among other properties, they are closed under non-negative addition, under the addition of any

scalar, and under multiplication of non-negative members of the class. Examples of the above programming problem with monotonic increasing constraint functions are found in many chance-constrained programming problems.

TP6.10 Successive Approximations and Infinite Horizon Discounted Sequential Decision Processes, EVAN L. PORTEUS, *4943 Manitoba Drive, Alexandria, Virginia.*

A new light is cast on the efficiency of successive approximations in analyzing many infinite horizon discounted sequential decision processes. The susceptible processes are those which satisfy, in addition to Denardo's "contraction" and "montonicity" properties, a new property, termed the "α-additive" property. Three results help to shed this new light. First new and improved bounds on the optimal (infinite horizon) return function are found. Second, new and improved bounds on the absolute difference between the return from following the "best" present policy over an infinite horizon and the optimal return function are also supplied. Third, the possibility of identifying certain decisions as being non-optimal at each iteration is found to exist. Thus, the set of decisions to be examined at an iteration can contain fewer elements than the set examined during the previous iteration. Several computational schemes are exhibited.

TP6.11 An Optimality Condition for Discrete Dynamic Programming With No Discounting, ERIC V. DENARDO and BRUCE L. MILLER, *The RAND Corporation, 1700 Main Street, Santa Monica, California.*

In this paper we consider the discrete time finite state Markov decision problem with Veinott's criterion of maximizing the Cesaro mean of the vector of expected returns received in a finite horizon as the horizons tend to infinity. A necessary and sufficient condition for optimality is obtained, and at the same time we verify Veinott's conjecture that there are optimal stationary policies.

TE1 George Elbert Kimball Memorial Session, CHAIRMAN: ARTHUR A. BROWN, *Arthur D. Little, Inc., Cambridge, Massachusetts.*

The Operations Research Society has suffered a grievous loss in the death of George Elbert Kimball, on December 5, 1967. He was a founding member of ORSA, a member of its first council and later its President. With Philip M. Morse, he authored the first generally-recognized text in Operations Research. He was also a member of many other worlds, in all of which he was held in affection and respect. This session will provide an opportunity for George Kimball's friends, colleagues and students to honor his memory and his contributions to science.

TE2.1 *Use of Simulation in Teaching Production and Inventory Control, ELI S. MARKS, *University of Pennsylvania, Philadelphia, Pa., 19104.*

In Operations Research, formulation of the problem is frequently more difficult (and more important) than finding a solution. The quality of a problem solution is, in fact, dependent upon the manner in which the problem is formulated (i.e., upon the model used). To give the students experience in problem formulation (model Building) a (general) simulator of production and inventory systems was

developed. The simulator permits either single product or multi-product inventories a 3 levels—raw materials or components, finished products at plant or central warehouse, components *or* finished products at (decentralized) "distribution points." The instructor has great flexibility in specifying the parameters of the system (distributions of demand and lead times and the various cost components) and can determine which system operating data are to be made available to students (which initially and which upon request). The simulator was used (experimentally) at Case Institute for teaching a course in Production and Inventory Control. After revision, it is currently being used as a teaching device at the Operations Research Institute of the University of Mexico.

TE2.2. *A Remote Terminal Application in Mathematical Programming Instruction, JOSEPH L. BALINTFY, *Tulane University, New Orleans, La., 70118.*

An IBM 1050 terminal connected to a 7044 system at Tulane has been programmed in FORTRAN to read format free matrix data and English commands. The terminal printout demonstrates the computational steps and solutions involved in basis changes, optimization, and parametric postoptimality evaluation of Linear Programming sample problems in a dialogue form. The device is used along with off-line computer models to teach an introductory course in mathematical programming.

TE2.3 *A Gaming—Monte Carlo Simulation Approach to Teaching Some Fundamental Concepts of Operations Research, THOMAS E. VOLLMANN, *Dartmouth College, Hanover, New Hampshire, 03755.*

A combination of business gaming and Monte Carlo simulation is used. Manufacture of a single imaginary product requires three decisions for each period; product quantity to be manufactured, raw material quantity for regular delivery, and raw material quantity for higher cost special delivery. The objective is to minimize the sum of several costs (inventories, production level changes, etc.). The three decisions require "decision mechanisms" which evolve through a variable series of assignments, being imprecisely formulated for the first assignment but evolving into unambiguous computer-programmed sets of decision rules or policies which in turn are refined. Long run efficacy of rules is evaluated through Monte Carlo simulation. The process of evolving decision rules, both for a particular assignment and for additional assignments, has several significant pedagogical strengths. First, students learn how to analyze stochastic situations as well as how to formulate, evaluate, and evolve policies for good, not optimal, solutions. Second, students develop awareness of sub-problem solution interactions and the way in which sub-optimization is reduced through more inclusive problem delineation. Third, students become equipped to use particular tools (*e.g.* forecasting by exponential smoothing) and to understand the tools' inherent strengths and weaknesses. The assignments are challenging regardless of student background, and high motivation levels have been experienced.

TE2.4 *The Use of Computers in Teaching O.R. (Panel and Demonstrations), CHAIRMAN: ELIEZER NADDOR, *The Johns Hopkins University, Baltimore, Maryland, 21218.*

The discussion will be devoted to a review of various O.R. courses in which computers are used, and to a forecast of possible future applications of computers to the teaching of O.R. Specific topics will include inventory systems, linear programming, game theory, queueing, critical path method, and simulation. The use of computers for model building, optimization, and for formulation of heuristic decision rules will also be discussed. The pros and cons of the use of batch processing and time sharing for teaching will be discussed. An example of a simulator (for use in a time shared system) that has been proposed as a means of instructing operating personnel in the use and interpretation of the results of an O.R. study will be presented. An ASR 33 teletypewriter and an IBM 1050 terminal will be available to communicate with computer systems at Berkeley, Darmouth, and Tulane, and with the G.E. Time Sharing System and IBM's QUICKTRAN service.

TE3 Workshop: Research Methodology for Management Psychology, CHAIRMEN: H. A. HOVERLAND, *Naval Postgraduate School,* and J. M. KEENAN, *Western Michigan University.*

Participants will work toward the development of a structural framework for classifying methodological problems. Practical difficulties in conducting research programs will be stressed. If you are interested in participating, please contact one of the Chairmen.

FA1.1 Techniques in Vulnerability/Survivability Analysis, G. W. BOWEN, *Fort Worth Division, General Dynamics, Fort Worth, Texas.*

Increased use of U.S. aircraft in Southeast Asia has demonstrated a need for designing new aircraft or modifying existing ones to reduce attrition due to conventional small arms and automatic anti-aircraft artillery threats. The susceptibility of aircraft to kill or damage is measured in terms of vulnerable areas, i.e., areas of critical systems or components which, if destroyed or damaged, would result in a certain level of kill to the airplane. A methodology to determine these vulnerable areas is presented, and associated models to evaluate the probability of kill, given an encounter with either contact- or proximity-fuzed threats, are described. Vulnerability reduction techniques are discussed in general, and a cost-effectiveness criterion is presented which is used to evaluate the resultant benefits and penalties incurred from the implementation of such techniques. The technique is based upon attrition cost reduction and is used to determine if a modification is cost-effective and, if so, at what level of aircraft usage it occurs.

FA1.2 A System Analysis of Motor Transport Operations in the Saigon Area, W. H. TETLEY, *Philco-Ford Corporation, Fort Washington, Pennsylvania.*

The problem of clearing a seaport of cargo by the use of motor transport has been formulated into a Host Resource Model. The cargo successively occupies a series of host resources, one of which is Motor Transport. This paper examines the essential parameters of the motor transport system first qualitatively and finally quantitatively using actual field data. Motor Transport, as a system, can-

not function in isolation. Actually, it is tightly coupled to its operational environment; consequently, the parameters of the consignor and consignee systems affect motor transport effectiveness to a considerable extent. This paper examines the enroute and queuing time distributions, mission to cycle-time ratio, and utility and performance indices. Real world examples indicate that the mission to cycle-time ratio is a relatively stable parameter whereas the effectiveness index fluctuates widely due to daily environmental factors.

FA1.3 Optimal Plant and Expansion, M. KLEIN, *The Dow Chemical Company, Midland, Michigan.*

The capital investment decision is not optimal unless original capacity and subsequent sizing and timing of expansions are subjected to maximization. This requires determination of cost and capital as functions of capacity, production load, and time. Empirical nonlinear functions for initial and subsequent costs are presented, and a method of coefficient determination is proposed. These methods are applied in a numerical example utilizing net present values. The resulting system is solved by a proposed simple heuristic method.

FA1.4 A Graph-Theoretic Approach to Assembly Line Balancing Solution, H. HESKIAOFF and J. WEINSTEIN, *Western Electric Company, 222 Broadway, New York, New York.*

This paper presents the development and the programming techniques of a heuristic method to balance assembly lines using directed graphs and their properties. The method employs the adjacency and reachability matrices to establish a precedence relationship whereby the tasks are assigned priorities based on their times and positions in their alternate paths in the network. The algorithm accepts many restrictions imposed on the lines such as mandatory assignment of some particular tasks to certain stations or operators, assigning more than one operator per station if necessary, and takes into account the speed of the operators due to lack of experience. The economic significance of the techniques used to substantially reduce the computer processing time and achieve a very high efficiency is also discussed.

FA1.5 A Family of System Simulation Models, A. P. FEDDERSEN, *Autonetics Division of North American Rockwell Corporation, Anaheim, California.*

Simulation is an operations research tool especially suited to the design and analyses of complex systems. As such it allows for the evaluation of alternative system designs by manipulation of the operating rules, policies, and variables comprising the system. The gamut of simulation models can perhaps best be classified along a continuum. At one extreme are the math models; as we move to the right, we introduce more human behavior into the models in terms of "target" and "object" where target is *what* is simulated and object is *how* it is simulated. However, beyond developing a taxonomy of simulation models, this paper is concerned with a class of models treating the significant analysis aspects of the acquisition and operational phases of an Aircraft Avionics System. The four models are briefly: 1) A generalized *production and test* model simulation involved with

validating production planning and determining bottlenecks to enable production schedules to be met; 2) A simulation model with emphasis on the *flight-line* portion of aircraft operation to validate alternative maintenance approaches under differing parameters; 3) A Monte Carlo simulation model specifically designed to measure system reliability for the *mission* portion of the aircraft operation; 4) A simulation model evaluating the field ship and depot echelons of maintenance and their interactions under various maintenance philosophies. Finally (and most important), the insights acquired by development of these models for theory testing are included. In the discussion are compiled the experiences realized with simulation models, their advantages and disadvantages, and a comparison with analytical models for treating the same problems.

FA1.6 Applications-Oriented Operations Research: A Case History in Optimum Inventory Scheduling, GEORGE SCHUSSEL, *Brown Engineering Co., Huntsville, Ala.*, and STEVE PRICE, *Northrop Corporation, Hawthorne, California.*

Four computer programs that perform what were formerly management decision functions in inventory scheduling are described. The first program solves the classical EOQ problem (uniform inventory usage) with quantity discounts. The second program, Economic Requirement Batching (ERB), uses dynamic programming, a heuristic search algorithm, and the relationship between shipment size and material cost to locate the optimum delivery schedule for any deterministic schedule of discrete (irregular) requirements. The third program, the Alternative Delivery Schedule Evaluator (ADSE), compares any alternative delivery schedules that meet requirements. ADSE calculates all costs associated with inventory and displays the optimum alternative and opportunity losses incurred by inferior alternatives. The fourth program, the Alternative Delivery Schedule Generator (ADSG), solves the difficult problem of optimally scheduling inventory in those cases requiring vendor production to special specifications and, accordingly, where the exact price of the item is unknown and depends on the manner in which it is produced. This situation is differentiated from ERB because ERB analyzes standard vendor shelf items which can be delivered according to any schedule. With little input data, ADSG generates a few highly efficient altenative delivery schedules upon which the vendor quotes. The returned bids are then evaluated by ADSE which determines the optimum delivery schedule.

FA1.7 Optimal Inventory Operating Policies under Relaxed Delivery Assumptions, LIEUTENANT JOHN M. COOK, *Naval Postgraduate School, Monterey, California.*

Historically, the inventory control problem has been analyzed under the assumption that the exact quantity ordered was delivered in one segment at the end of a probabilistic or deterministic leadtime, or alternatively, that receipts result from a continuous fixed rate in-house production process. In this paper the effects of relaxation of these assumptions are considered, tending toward models with delivery conditions more nearly approximating conditions confronting large inventory systems. Contracts providing for delivery of short or excess quantities within tolerances and for incremental deliveries are common. Production rates are

often stochastic due to the diversion of resources to meet higher priority random demands or other external conditions. These and other conditions are considered in this paper. The optimal operating policies and costs are compared to the policies and cost resulting from the conventional assumptions.

FA1.8 A Bilateral Optimal Lot Model, GORDON K. C. CHEN, *School of Business Administration, University of Massachusetts, Amherst, Massachusetts.*

Numerous models of economic order quantity have appeared in various literatures for many years. Most of the work, however, considers the problem primarily from the buyer's or user's point of view. Little attention has been given to the possible impact of the buyer's EOQ decision on the seller. This paper discusses a theoretical model which takes into consideration the interaction between the buyer and seller with respect to their decisions on the order quantity. The model attempts to show that there is an equilibrium point where both the buyer and seller will settle for the order quantity so that neither of the parties can gain more by changing it.

FA1.9 CPM Implementation in the Construction Industry—A Dream or Challenge, CHANDRA K. JHA, *Tishman Construction Company, 10 South Riverside Plaza, Chicago, Illinois.*

It is almost a decade since the CPM and PERT were introduced in the construction industry. The basic system, though simple in concept, has always been a difficult task to implement. Since its introduction, there have been many developments in both the hardware capabilities and the techniques of data processing. Consequently, the system today, if properly implemented, can truly become an integrated information system for the project(s). Despite many developments, a very few companies in the construction industry can claim success in implementation of the system. The primary cause for such a gap between the development and implementation of the system is the interface between the computer output (canned program) and the man in the field. Until we are able to customarize a computer output which the construction man with a little orientation can understand, no sophistication either in the hardware or in the system design can bridge this gap. The author will demonstrate with a specific project, currently being implemented, causes of the failure in implementation of the system and will propose how the gap between the development and the implementation can successfully be bridged.

FA1.10 The Role of the Time-Sharing Medium in Management Decision, DONALD J. FORGIE, *The Ontario Paper Company Limited, Thorold, Ontario, Canada.*

Emphasis of the paper will be on time-sharing capabilities with reference to experience gained in using three separate time-sharing systems with different language and programming capabilities. The paper will show how a time-sharing capability can be used to up-date input information of a model of a pulp and paper company (from raw material to finished product output), and receive the output information from the large linear programming model to generate reports for each

functional area. The use of the time-sharing capability for interactive use in decision meetings by senior executives for planning and operational decisions will be discussed. The paper will deal with theoretical problems as well as operational experience with its use. The value of human factors research in assisting management in dealing with the new capability will be discussed.

FA1.11 Characteristics of a Processor-Shared Model of a Time-Shared, Facility, JOHN W. MCCREDIE, JR., *Carnegie Mellon University, Pittsburgh Pennsylvania.*

Many modern systems, such as some computer configurations, share a large central facility among numerous users. Economies of scale, and a certain commonality of resources are advantages that are paid for by higher overhead costs due to complex designs. The characteristics of a continuous time Markov model useful in studying such systems are presented. Basic dynamic and equilibrium state equations are examined to determine system parameters such as the expected transit time of a request and the distribution of the number of users in the system. The model requires exponential assumptions concerning interarrival time of service requests and service requirements. Simulation tests explore the robustness of these assumptions. Methods of incorporating overhead costs, and non-homogeneous user classes are presented. The potential of the model in a control framework is outlined.

FA1.12 Measures of Effectiveness on a Real Time Basis, WALLACE M. COHEN, *Technical Operations Inc., 101 Lincolnia Rd., Alexandria, Virginia.*

In human gaming situations the dynamics of the experiment over time make it necessary to monitor the play of the game on a real time basis. This precludes placing too much weight on the analysis of data after the play of the totality of game play. It does require evaluation of monitored data at appropriate time frames during the game; hence allowing players in a game to have that information which would influence their action in a non-experimental environment. A procedure has evolved that allows human gaming situations to be more realistic when contrasted to the "real world." The concept, which will be presented, evolves around the design of appropriate measures of effectiveness that allow for interface between man and computer on a real time basis, the computer being the depository of data and the various measures of effectiveness. This concept embodies a synthesis game play and the measures of effectiveness.

FA1.13 Computerization: Some Implications for Decision Making, G. H. PERRY, *System Development Corporation, Santa Monica, California.*

Decision making is discussed both in a broad economic context and in a specific definitional sense, and is then related to the informational revolution, or computerization. The directional and dimensional changes in the decision making process that appear to be imminent or already underway are described, and predictions are made of the effects these changes will have upon managers' jobs in the near-term future.

FA1.14 A Bayesian Approach to the Problem of Engineering Research and Test Expenditures Under Conditions of Uncertainty, GENE R.

SIMONS and RUSSELL C. KOZA, *Rensselaer Polytechnic Institute, Troy, New York.*

A model is developed in this paper to aid the decision-maker in evaluating the worth of exerting additional engineering and test expenditures on a producible and marketable product. The technique utilized involves the use of Bayesian statistics in a concise matrix algebra format which is highly suitable for computer programming. A typical problem involving the development of a technologically-based product is presented and the solution technique applied. Additionally, a method of determining the sensitivity of the model to the originally estimated parameters is developed and illustrated which is used to determine the feasible range of model application.

FA1.15 The Determination of the Relative Value of Research Tasks Using the Law of Comparative Judgment, RAY SORRELL, *International Business Machines, 4800 Rugby Avenue, Bethesda, Maryland,* and HARRY GILDEA, *Peat, Marwick, Livingston & Co., 1140 Connecticut Avenue, N.W., Washington, D. C.*

In a recent study of lifting bodies for reentry research, a methodology was established for determining the relative values of the various proposed tasks. The value of each research task was derived using the Law of Comparative Judgement, information theory, and probability theory. The "intrinsic value" of 52 research tasks was determined on the basis of paired comparisons performed by 11 engineers and scientists. The intrinsic values were modified to reflect various options with respect to environmental conditions and the probabilities of experiment success. A computer program was used to determine the final relative values from the source data.

FA1.16 Model of the Management Process as a Framework for Analysis and Understanding, C. W. WOJ, *General Refractories Company, Philadelphia, Pennsylvania.*

There is a continuing need for a universal understanding and delineation of the fundamental process of management. This need does not concern the economic objectives nor personal objectives of managers but, rather, the inter-related mechanism of the combined and singular actions of managers, the sum of which determine an organization's performance. In answer to this need, this paper examines the "management process" by defining its components and developing a verbal and corresponding mathematical model to represent the process. The model recognizes behavioral, economic, and logic factors as opposed to embracing any single doctrine. Present and potential uses of the model are presented for consideration. Finally, a prediction of the future structure of management is made based on an analysis of the current forces at work in the universe of business management.

FA1.17 Causative Analysis, JOSEPH BODO, *Sylvania Electronic Defense Laboratories, Mountain View, California.*

Delineating the foreseeable or search for plausible sequels to the present is said to be mostly an art, based on intuition, heuristics and expertise. Yet an examination of the logical, structural and relational aspects of "research into the future"

indicates the possibility of a pseudo-science of prediction. As an attempt toward this aim, a formal method based on the morphological analysis and structural representation of the spatio-temporal contiguity of events and attributes—to include past, present, and future projections—is outlined. Following a study of the typology of casual relations, general methods for identifying causal relations and functional correlatives are presented. Tests for temporal precedence, contemporaneousness, spurious correlation, spurious independence, intercorrelation, and indetermination are described. To facilitate continuous prediction concepts and measures of structural and causal stability are developed. The predictive power of causative analysis is examined and the possibility of discovering hidden antecedents, latent trends, and emerging possibilities using this method is considered.

FA1.18 Theoretical Foundations for Teleological Systems, JERRY L. SANDERS and COLONEL JACK M. POLLIN, *The University of Arizona, Tucson, Arizona.*

The "traditional" system theories which employ the concept of state and state transition have been extensively explored by such authors as Moore, Zadeh & Desoer and most recently by Wymore. Unfortunately it appears to be extremely awkward to apply these concepts to systems whose most natural formulation is in terms of a goal-seeking description. Those problems whose formulation involves the statement of an optimization problem of global nature seem to require an alternative point of view. This paper focuses on the class of teleological or goal-seeking systems with the purpose of formalizing a theoretical foundation for furthering the analysis of such systems. Starting with the fundamental elements, such as input, output, goal, duration of operation, etc., that are common to all such systems a set-theoretic definition is presented and explained. In illustration, the appropriateness of the definition offered to examples from several areas of OR interest is examined, and the equivalence of various systems is explored. The examples thus analyzed, themselves represent broad classes of previously defined systems, e.g., finite-state machines, input-output state described systems, and systems of differential equations, and indicate the possible scope of application of the basic theory to areas of interest to operations research analysts.

FA1.19 The Modeling of Consumer Markets for an Adaptive Marketing Decision System, KERRY CURTIS, *University of Pennsylvania, Philadelphia, Pennsylvania.*

For the behavioral modeling of consumer markets to be of maximal use for management, a model must be available for the evaluation of any proposed marketing policy in any geographical area. Models must be developed and maintained with which management is familiar and in which they have confidence; consequently, management's participation in the research is necessary. The study is being conducted for a branded, nationally-distributed food product. A conceptual system for incorporating past experimental work, both macroscopic (large scale advertising experiments) and microscopic (individual interviews and laboratory work), with historical sales data and management's experiential under-

standing has been developed. Consumer-based models have been developed and are being tested which yield predictions, for any set of policy variables, of the market shares of the several brands of the product. The basic model is based on consumers' perceptions of the values of the brands; the roles of price, advertising, displays and distribution are cast in those terms. A simulation model is used to map the distribution of consumers' values and the policy-state of the market into a market-share prediction. Population segmentation is based on demographic and psychological characteristics, but only where differences between the distributions of value perceptions permit discrimination.

FA1.20 Utilization of a Patient-Care Model, DANIEL HOWLAND, *The Ohio State University, Columbus, Ohio.*

Recently enacted health legislation is having a number of effects on health systems. In addition to the growing allocation of resources to health systems, there is a growing requirement for integration of the various components of these systems. The most important components are the nurse, the patient and physician. Only by looking at the interactions between these components can system effectiveness be judged. Effectiveness must be measured relative to the patient-centered consequences of resource allocations. Other criteria, such as the time the nurse spends with the patient, may leave important questions (such as the impact of the nurse on the patient) unanswered. A patient care measure to assess the effectiveness of hospital resource allocation decisions has been developed in the framework of a model describing the interactions of the nurse, patient and physician. Using this model to guide our research, a pilot study of five surgical patients has been completed. Data, collected by a team of registered nurse observers, describe the reaction of the patient to hospital resource allocations from admission to discharge. The data show the demands of the patient on the system, the system response, and the consequences for patients. A preliminary analysis of the data has been completed, and some tentative results obtained. Methods of data collection, the analysis and the results will be presented.

FA1.21 Planning the Allocation of Effort to Projects Under Uncertainty, JOHN O. TOLLEFSON, *The University of Kansas, Lawrence, Kansas.*

A procedure for planning the allocation of effort to projects under uncertainty is presented. The procedure utilizes statistical decision theory and a generalized Lagrange multiplier method. The procedure generates efficient (or undominated) effort allocation plans where: 1) discrete alternative levels of effort are recognized for the various projects; 2) the level of effort applied to a project may be adaptively modified at project milestones; and 3) project outcomes are, in general, uncertain.

FA1.22 Risk Aversion in Contract Negotiation, JOHN P. SEAGLE, *State University of New York, Department of Management Science, Buffalo, New York.*

Contract negotiations between government agencies and private firms provide an unusual opportunity for study of the risk taking characteristics of negotiators and of business organizations. For the usual transaction between business firms, the seller bears all unforeseen costs and receives unplanned savings. In govern-

ment procurement, however, a variety of cost and profit sharing arrangements are commonly used. An examination of some preliminary data has shown that several sharing arrangements as well as several target prices are sometimes among the offers and counteroffers between two parties for an unchanged set of tasks. Extreme examples were noted in which price ceilings were required of contractors in exchange for higher target prices than for a contract having unlimited cost sharing. Negotiation data are being studied for evidence of risk aversion or preference among firms that are both large and small with respect to the size of the contracts concerned. Related research by an interdisciplinary team will deal with the behavioral effects of various contractural arrangements, including cost sharing. This study proposes to measure the cost to the buyer of passing risk to a contractor.

FA1.23 Depreciation—A Model for Estimating the Opportunity Cost of Different Styles and Rates of Facility Utilization, MILES KENNEDY, *Sloan School of Management E53-330, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

A general but operational model for the estimation of opportunity-cost depreciation is developed. This model serves two basic purposes. In the first place, decision-makers faced with alternative strategies implying different styles or intensities of facility utilization must now fall back on full-scale capital budgeting models to select the optimal strategy. Use of this depreciation model should offer a considerable saving in time and effort which will be particularly valuable in the day-to-day control of job shop and similar facilities. But secondly, a sensitivity-testing of the model offers valuable intuitive insights into a number of hitherto unresolved problems. It is shown, for instance, that the commonly-employed depreciation methods (straight line, declining charge and annuity) are all special cases of this more general model and discrepancies between these rule-of-thumb procedures and the model are investigated. The model is also found to provide some interesting insights into the related problems of second-hand markets, optimal policies of down-grading to stand-by status and the relative depreciation costs of assets on first-call and standby status respectively.

FA1.24 User Designed Computer Systems for Medical Research, CHRISTOPHER E. NUGENT and THOMAS E. VOLLMANN, *Dartmouth College, Hanover, New Hampshire.*

In designing computer-oriented Management Science-based systems for medical research, designers face (even more acutely than in business environments) a gap of understanding, appreciation and knowledge between themselves and the system users: medical men do not have technical system design expertise and designers are ignorant of medical needs. The authors believe traditional methods will lead to the design of systems which, even if initially successful, will soon prove inadequate because of evolution in the users' needs as they accumulate experience with the system. User-requested changes will become increasingly difficult to implement and the above mentioned gap will grow, leading to ineffective systems. The authors believe that modern computer technology may make possible a shift in the roles of the designers and users in which the designer's task is to create the proper computer

environment for the user to design his own individualized computer system. This was impossible formerly because of the inaccessibility and unwieldiness of computer power. Research involving the Dartmouth Time-Sharing System and medical personnel has led to the development of a medical computer language allowing users to assume more of the system design function and obtain individualized massive computation power with a minimal learning investment.

FA1.25 The Integration of Systems Analysis and Program Budgeting in University Planning and Administration, JACK B. LEVINE and RICHARD W. JUDY, *University of Toronto, Toronto, Ontario.*

The integration of long range resource planning tools with the short range budgeting process is explored in this paper. A specific example of an institutional application of the approach is discussed. At the University of Toronto work has been underway for two years, on the development of a systems simulation model for resource planning. The model accepts statements of planned programs (courses, research programs, etc.) and the levels at which these programs are to be carried out in the future. This information is combined with decision information on such matters as class size and professorial teaching loads, to simulate the impact of this proposed plan on university resources. An annual programming budget cycle is being established, that is from a logical point of view carried out in much the same way as the process that the model goes through in forecasting resource requirements. Since the general process follows the logical flow of the simulation model it gives the administration confidence in using the model to investigate the impact on resources of various configurations and programs. Exploratory studies carried out on the model give various program directors and chairmen experimental results to be used in actually determining the programs and levels of the programs to be carried out in the university.

FA1.26 The Use of Effectiveness Measures in Decision-Making by Local Government, DON H. OVERLY, *Wayne State University, Detroit, Michigan.*

There is an urgent need in local government for a methodology which will permit a rational, or goal-oriented, allocation of resources. A major difficulty, both theoretical and practical, is the development of practical effectiveness measures which are representative of goals and which can measure the relative success, or efficiency, of achieving goals. A practical methodology has been developed for a local police department. The principles and techniques of this methodology can be applied to the larger resource allocation problems of local government and to urban problems in general. This methodology is based upon the basic goals of a local government rather than the relatively limited norms of a police department; i.e., the goals of the police department are derived from larger goals. Also, many of the inherent limitations of police departments are considered. This methodology is based upon the careful definition of goals as desired "categories of criminal and noncriminal behavior." Each category and subcategory is defined and understood according to a vocabulary of "policy and program variables." These variables, ideally, will measure the final impact of police resources upon the community or social system. By treating each category and/or subcategory of criminal and

noncriminal behavior in a matrix format, and by analyzing alternative sets of matrices where each matrix represents one category of behavior, it is possible to apply in a realistic fashion cost-effectiveness and cost-benefit techniques. This approach allows direct consideration of both the administrative and budgetary limitations of a large police department. A major consideration here is the development and operation of this methodology with reference to the urban political environment and the pluralistic form of local government. Also, consideration is given to the application of this methodology to other areas of local government.

FA1.27 Use of Cost-Benefit Analysis in Solutions to National Health Problems, HARRY E. EMLET, JR., *Analytic Services, Inc., 5613 Leesburg Pike, Falls Church, Virginia.*

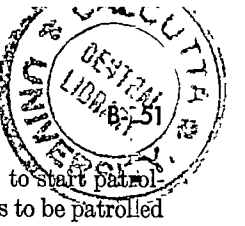
Rapidly burgeoning medical needs and soaring costs are making action on a national level increasingly urgent. The possibilities for action to alleviate these problems are many, and the national resources are, and will continue to be, much more limited than the many possibilities for applying them. The alternatives for action offer benefits that very in type and quantity and entail different costs. Cost-benefit analysis offers a means of rationally selecting a preferred course of action to maximize benefits received for resources invested. Possible measures of merit are discussed, a common measure of merit is suggested, and an analytical model applicable to programs for screening and controlling diseases is developed. Variations of the model are discussed, and an application of one version is illustrated.

FA1.28 A Cost Effectiveness Study of County Road Building and Maintenance Systems, RONALD A. NELSON, *Box 643, Rockville, Maryland.*

At the local government level, cost effectiveness techniques have not been widely applied to the road building and maintenance system. The objective of this paper is to present a methodology with which to guide the development of the most efficient resource allocation scheme and associated management structure for building and maintaining roads at the county level. Three tasks have been accomplished. (1) A methodology for measuring the cost effectiveness of a road building and maintenance system at the county level was developed. (2) Several alternative resource allocation schemes and management structures for this system were hypothesized, and the most efficient alternative as a function of a set of controlling parameters was determined. The possible forms of management structure ranged from the wholly decentralized (only township control—no county control) to the wholly centralized (no township control—only county control). (3) The most efficient method for changing from the existing to the most efficient system was determined as a function of assumed budget constraints. The implementation of this methodology to the extent allowed by the collected data is illustrated.

FA1.29 Random Patrol Scheduling, MATTHEW ROSENSHINE, *Cornell Aeronautical Laboratory, Inc., Post Office Box 235, Buffalo, New York.*

It is hypothesized that the introduction of randomness into patrol schedules increases the effectiveness of patrol in accomplishing its ends. The problem of scheduling random patrol is broken down into two smaller problems—the problem



of selecting route and the problem of when (or equivalently where) to start patrolling. The first problem is solved by considering the streets or routes to be patrolled as a network each having a minimum required patrol rate. If there is a feasible solution, that is if the specified minima can be met with the resources available, then the patrol rates to be assigned are those which maximize the linear function $\sum_{i=1}^{r} \mu_i e_i$ where r is the number of route segments, μ_i is the patrol rate on the ith arc, and e_i is the marginal effectiveness of the minimum required patrol rate on the ith arc. Randomizing the patrols is accomplished by first, drawing the elapsed times between the dispatch of successive patrols from an exponential density with parameter equal to the mean rate at which patrols are dispatched and then determining the path to be taken out of each node by dividing the patrol rate of the particular segment by the sum of the patrol rates for all route segments emanating from this node. This randomness can be superimposed on the solution to the routing problem.

FA1.30 Models for Optimizing the Use of Housing in New Towns, JOHN W. DICKEY, *College of Architecture, Virginia Polytechnic Institute, Blacksburg, Virginia 24061.*

A problem which seems to occur in new towns is that of the cycling of the demand for various facilities caused by changes over time in the family size (and type) distributions in the town. In this paper an attempt is made to determine the number of each size of family which new town managers should attempt to attract to new towns in order to minimize certain costs attributed to the cycling of demand for *housing*. Four different situations are considered: 1) When the objective is to minimize the number of vacancies and unfulfilled demands; 2) When the objective is to minimize the number of houses needed; 3) When the objective is as in (2) and the probability of a family being of a given type is the same as that in a representative existing population; 4) When the objective is as in (2) and the probability of a family being of a given type is the same as that in a representative *moving* population.

FA1.31 A Systems Approach to Employment After Orthopedic Rehabilitation, HARRY A. GRACE, *University of Southern California, Los Angeles, California.*

Employment is a primary objective for the rehabilitation of orthopedically disabled adults. To systematize an approach to this goal, a survey was made of 154 employers in Southern California. From statistical analysis of the results, using the .05 level as significant, a decision table was derived that showed how employer characteristics related to the probability for placement. Characteristics included the size of workforce, type of firm, level of work, and technical skill of work. Employers indicated how many of their workforce had each degree of disability, how important each type of disability was to their firm, and how important modification of such disabilities was to the firm. The flow chart derived from these empirical results shows (1) the strategy for placement of orthopedically disabled persons according to employer characteristics; (2) employer attitudinal resistance as a function of experience with the orthopedically disabled; (3) attributes

expected of the orthopedically disabled according to the type of employer (e.g., manufacturing, service, etc.); and (4) topics on which rehabilitation programs must focus in order to meet employer criteria for successful placement.

FA2 Panel on: The Role of Planners and Planning in the Management Process and Structure, CHAIRMAN: RALPH F. BAXTER, *Avery Products Corporation, San Marino, California.*

The major points for panel presentations and discussions will be 1) The role of the planner in making strategy, 2) The role of the planner in giving technical expertise to the line manager making strategic decisions, 3) The role of planning methodology in the management process, and 4) The role of planning function in the corporate structure.

FA3.1 *On The Interface Between a Regional Transportation System and the Central Business District, LESTER A. HOEL, FRANK DICESARE and JAMES W. HOAG, *Transportation Research Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania.*

This paper deals with interfacing a regional rapid transit system with destinations in the central business district of a city. Various strategies of interfacing are to be tested and evaluated on the basis of level of service. An interface system is defined as that part of the system which takes passengers from some predetermined points in the regional system to their destination in the CBD. Examples of general strategies are: (1) the regional system penetrating the core and passengers debarking and walking to their destinations; (2) the regional system intersecting a secondary distribution system at one or more points whereby the passengers transfer from the regional system to the distribution system which takes them closer to their destination. The alternatives are evaluated using a model which considers the user's choice of route from point of origin to destination. The question of assumption of a users choice rule is discussed considering such extreme rules as minimizing total time or minimizing walk time. Since neither of these rules weigh fairly such user inconveniences as time spent transferring, time spent waiting for trams, etc., it is decided that the model should be capable of using a rule which is a weighted function of all parts of the trip. The model characterizes trips by their elemental actions and the relationships of the actions to the time taken in their performance are discussed and developed. The interface model allows all reasonable possible combinations of elements which form a complete trip from any origin to any destination to be tested and measured. Statistics for comparison of alternate strategies are then developed from the model. An accessibility measure is developed which essentially allows the policymaker to compare the average accessibility of destinations in the core from origins in the regional system. Various other statistics and forms of display of results are considered as a means for providing the policymaker meaningful information with regard to each system. The algorithms performing each of these tasks is discussed. An example, using data from an existing city, follows the procedure from the assumptions made in characterizing the elemental actions to the point where information is provided to the decision-maker.

FA3.2 *Merging Delays in Automated Ground Transportation Systems, MICHAEL B. GODFREY, *Department of Mechanical Engineering, M.I.T., Cambridge, Massachusetts.*

The automation of a ground transportation system adds a new dimension to the scope of traffic flow theory. Complete external control of scheduling, routing, merging, and individual vehicle dynamics not only encourages consideration of a widened spectrum of system operating strategies, but also leads to systems for which good models are far more readily constructed. From better models should come better performance estimates. This paper computes such estimates for a selection of merging strategies; we examine the merging delay statistics associated with a variety of rules for assigning rights-of-way when two traffic streams merge into one. Priorities are assigned according to queueing and arrival conditions at the merge. Since time headways are multiples of a minimum headway, a discrete-time model is appropriate. Steady-state delays are investigated analytically using light-traffic assumptions. Mean merging delay is shown to be independent of these merging rules, so that measures of effectiveness must be based upon either higher moments or percentiles of the delay distribution. Through Monte Carlo simulation, delay statistics for each merging strategy are estimated under typical rush hour conditions for a system in which automobile-sized vehicles operate at speeds of forty to sixty mph. An analysis of variance computes the sensitivities of these delay statistics to various flow pattern parameters. The steady-state analysis can be extended to simple networks. Several other approaches to the operation of a merge are discussed.

FA3.3 *A Model for the Simulation of Transfer Operations in Multi-Mode Transportation Networks, PAUL O. ROBERTS, JR., DONALD S. SHOUP and J. ROYCE GINN, *Harvard Transport Research Project, Harvard University, Cambridge, Massachusetts.*

Overall trip performance is largely dependent upon transfer operations. Although no distance is actually traversed, there is a lapse of time and an element of cost associated with a transfer. Consequently, the purpose of the Transfer Model described in this paper is the simulation of the transfer of goods and passengers from one mode of transport to another. A transfer facility in the real world appears to the model as two opposing links. This set of transfer links can be made to represent any form of intermodeal transfer: road to rail, rail to ship, ship to pipeline and so on. There is a large range of possible technologies which can be employed at a transfer terminal, each with an associated set of cost and performance characteristics. Operating times and cost data describing each of these loading and unloading technologies are described in a table of technology characteristics. The input to the model of characteristics describing a link requires merely an indication by class of the technology to be employed and the number of berths available. The assumption is made that bulk, general, special and passenger operations are carried on independently. Traffic flows between inbound and outbound nodes are presented to the Transfer Model by giving tonnages flowing over the link as well as the number of vehicles in and out. An m-server queuing model is used to represent

the berths of the facility. Output from the Transfer Model takes two forms. Facility performance measures are output directly by the Transfer Model showing queue lengths, queuing times and waiting times as well as statistics on facility operation which describes the way in which the facility operates from the viewpoint of the shipper.

FA3.4 *Conditional Networks in Intermodal Transportation Transfer Problems, ERNST G. FRANKEL, *Department of Naval Architecture and Marine Engineering, M.I.T., Cambridge, Massachusetts.*

A description of an application of conditional network theory to the port interface planning problem is presented, with particular reference to cargo stow, cargo planning and cargo sequence in a ship loading operation. The discussion includes an evaluation of the relative merits of a dynamic programming versus random search optimization procedure in such a problem subject to objective functions containing a mix of qualitative and quantitative factors.

FA3.5 *Determining Vehicle Size and Frequency of Service for a Short Haul Air Transport System, ROBERT W. SIMPSON and MICHEL NEUVE-EGLISE, *Flight Transportation Laboratory, Department of Aeronautics and Astronautics, M.I.T., Cambridge, Mass., 02139.*

To compete successfully in short haul markets under 200 miles, an air transport system must offer a high daily frequency of service, N, as well as short air travel times. In a given market, N can be increased by using vehicles of smaller seat capacity, C, which are more expensive per seat to operate. A method of determining optimal values of N and C for assumed market behaviour in terms of fare and time elasticities is presented. By defining total trip time to include the average wait for service, and using a demand model developed for the Northeast Corridor, the air share of total demand in any market can be calculated as a function of N and the competing fares. Plotting daily passengers versus N, and relating this to the maximum and breakeven load factors for a family of vehicles of different seating capacities determines the values of N and C which maximize return to the operator.

FA4.1 *A Systematic Procedure for Assessing the Worth of Complex Alternatives, JAMES R. MILLER III, *Graduate School of Business, Stanford University, Palo Alto, California.*

This paper addresses itself to the problem of assessing worth. It is assumed that a decision context has been specified and that a fixed set of discrete alternatives has been produced. It then remains to assess the worth of each alternative, to estimate the resource drains required by each, and to combine these considerations, along with considerations of risk/uncertainty, so as to arrive at a final decision. To aid in the assessment process, a detailed procedure has been devised. The purpose of this procedure is set forth, and step-by-step instructions for its actual implementation are presented. An experiment was performed whose purpose was to validate the procedure (i.e., to demonstrate that it could be carried out successfully). Major conclusions are that the procedure can be carried out successfully—at least by professional decision makers in a laboratory setting—and that all phases of

it exert an important impact upon the decision making process. Requirements to quantify worth notions induce decision makers to formulate and validate their preferences. An additional consequence is to provide an explicit and logically consistent assessment structure, which, if considered acceptable, may be used to guide a final decision. The procedure is both general and flexible with respect to type of decision, type of alternative, and type of worth criterion. However, its application may be restricted by type of decision-making personnel and certain contextual factors.

FA4.2 *Benefit-Cost Estimates for the Job Corps, GLEN G. CAIN, *Social Systems Research Institute, University of Wisconsin, Madison, Wisconsin.*

A number of benefit/cost ratios for Job Corps are reported in this paper. Different assumptions about the appropriate concepts and measures of the costs and benefits lead to ratios that range between .60 and 1.89. The interval from 1.02 to 1.70 is suggested as encompassing a set of ratios that are conservative and realistic. An important limitation of this study is that the sole measure of benefits is the improvement in labor market earnings of the Corpsmen. Two sources of data are used for measuring the benefits from Job Corps. One is a report of gains in reading and mathematics by Corpsmen. Existing studies of the relation between earnings and education provide a basis for translating the educational gains into expected future lifetime earnings. The second data source consists of two surveys conducted in February 1967 of: 1) a sample of ex-Corpsmen who left Job Corps during August 1966, and 2) a sample of applicants who were accepted for Job Corps but who did not participate in the program. The latter comprise a group with which the ex-Corpsmen are compared in terms of the median wage rates earned as of the survey date. Using conservative discount rates to translate expected future earnings into present values, the estimated present value of the improvement in lifetime earnings for the *average* Corpsman (*who is in the program about five months*) is between $3,600 and $5,900. The cost figures that are used are comprehensive and measure the different costs of varying average durations in the Job Corps. Nine months is the normal term for graduation, and five months is the estimated average stay for all Corpsmen—graduates and dropouts combined. The net costs of the average Job Corps experience for a youth (again *based on a five-month stay*) is estimated to be about $3,500. Benefit/cost ratios that are larger than unity, follow directly.

FA4.3 *The Production Function in the Public Sector: Production of Postal Services in the U.S. Post Office, LEONARD MEREWITZ, *Department of Economics, University of California, Berkeley, California.*

The objective is to measure efficiency in the operation of remote offices and to estimate production functions for post offices. Such a method for evaluating efficiency in other government activities may be practical with data forthcoming from PPBS studies. A quasi-concave programming problem is defined in which post offices are assumed to try to minimize cost subject to output constraints. A generalized Cobb-Douglas model is used here with factor prices and outputs varying cross-sectionally over 160 U.S. cities. A Post Office norm is estimated econo-

metrically from a subset of efficient offices. Other offices can be compared with this norm and directed to emulate those with efficient factor proportions. Returns to scale can be studied and an optimal size of office suggested. Recent work in the theory of multiproduct production correspondence suggests that a Cobb-Douglas formulation is inadequate for its assumed hypersubstitutability among factors and its perverse convexity in output space. The fruitful direction is to specify reasonable cost functions rather than production functions and make use of the duality between these two.

FA4.4 *An Optimal Allocation of Resources for the Capital Budgeting Problem, JOSEPH J. MODER, *Department of Industrial Engineering, University of Miami, Coral Gables, Florida,* and JAMES J. NICKL, *Lockheed Aircraft Corporation, Burbank, California.*

As the channels to which money can be allocated become greater in number, and their interrelationships become more complex, a systematic approach to budgetary decision making becomes essential. Such an approach is developed in this paper, assuming that the program under consideration has a fixed sum of money for allocation, which is insufficient to finance all of the alternative activities under consideration. A sequential procedure, utilizing the PPBS approach, is developed to evaluate the comparative worth of interacting alternatives in the capital budgeting analysis, and to maximize their combined benefit or effectiveness. While certain mathematical techniques are incorporated in the model, the general mathematical intractability of this problem is recognized. The need for open discussion, subjective opinion, intuitive insight and competitive bargaining are essential ingredients in the proposed systematic procedure. The mathematical formulations are designed to be an aid to the intellectual and experiential capabilities of the individuals involved in the study. Some applications of this procedure, especially in the context of Model Cities Planning, will also be presented.

FA4.5 A Cost-Effectiveness Framework for Urban Transportation Plan Evaluation, JOSEPH L. SCHOFER, *Department of Systems Engineering, University of Illinois at Chicago Circle, Chicago, Illinois.*

This paper presents a generalized strategy for the application of cost-effectiveness analysis to the evaluation of urban transportation plans. The structure of the cost-effectiveness approach is described, and the major differences between the proposed methodology and traditional benefit-cost analysis are discussed. These differences are shown to result in the considerable advantage which cost-effectiveness presents over the more common evaluation techniques. This is particularly true in cases where social, psychological, aesthetic, or other consequences of alternative plans result in many intangible or incommensurable factors which must be considered in the decision process. A generalized model of system effectiveness based on a conceptual model of the transportation system and its interface with its environment, as well as on unique local objectives, is presented. Several hypothetical examples are then introduced to illustrate the application of the proposed methodology to operational transportation planning processes.

FA4.6 Using Estimates of the Enemy's Cost and Effectiveness to Weight Threats, THOMAS G. BUGENHAGEN, *Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland.*

The effectiveness of defensive weapon systems is often analyzed by calculating a performance index of the system against a spectrum of postulated threats. Since the threats are rarely considered to be of equal importance, some index other than the arithmetic average is usually necessary. This implies the use of weighted averages with the weightings chosen to reflect the 'importance' or 'likelihood' of the respective threats. However, the idea of using weighted averages has generally not been well received since, in the past, the weightings have often been subjective and somewhat arbitrary. It has sometimes been suspected that the weightings were chosen to benefit a preferred system. The author has found that when estimates of the enemy's cost and effectiveness are used to weight the threats, opposition to the idea of weighted averages nearly vanishes. In this paper, the enemy effectiveness is measured by estimates of his probability, P, of damaging the target, and defense system effectiveness is measured by the probability the target is not damaged. It is shown that a threat weighting based on the enemy's effectiveness cannot be simply P, but must be some function of P such as $(1 + P)$ or $(\frac{1}{2} + P^2)$ in order that consistent results be obtained.

FA4.7 A Model to Assist Army Force Planners in the Evaluation of Multiple Measures of Effectiveness, THOMAS A. MAHAR and ANTHONY J. PELLEGRINI, *Research Analysis Corporation, McLean, Virginia.*

RECAP is the acronym given to an automated model developed to assist Army force planning by providing information on both the *RE*source requirements and pre-combat *CAP*abilities of alternative force structures. The model operates primarily as an information retrieval system with an automated data base. The data library currently contains 17 separate resource measures and 53 measures of force capability coded to either battalion level force elements or, in the case of major equipment, to the items themselves. Examples of such measures are ownership costs for any number of years, total direct and indirect firepower, maximum troop lift capacity, number of pilots, total payload-carrying capacity over poor roads, etc. The user of the model selects from the library those measures of importance to his application. Output consists of general linear aggregations of both the cost and capability factors related to alternative force structures. In addition, the model displays by measure the relative rankings of each alternative. One feature of the model worthy of special attention is a provision allowing the size and mix of alternative forces to be adjusted to provide a comparison of forces at an equal level of any one measure. For example, candidate force structures can be compared on the basis of equal cost, equal firepower, equal strength or the like, thus eliminating one of the variables from consideration. Structuring equal cost alternatives is one very valuable use of this feature since a fixed cost criterion is thus provided for cost-effectiveness comparison.

FA5.1 Optimal Priority Assignments in Queuing, DANIEL P. HEYMAN, *Bell Telephone Laboratories, Inc., Holmdel, New Jersey.*

Customers arrive at a service facility according to a Poisson process; they are divided into p priority classes, and a holding cost of h_i [\$/customer-hour] is charged for each member of the ith class who is delayed in the queue. We define an optimal policy as a nonpreemptive priority scheme that minimizes undiscounted cost per unit time over an infinite horizon. Using the theory of Markov decision processes we obtain a simple derivation of the optimal priority assignment for the $M \mid G \mid 1$ queue with limited queue size and the $M \mid M \mid c$ queue with different service rates in each channel.

FA5.2 Analysis of a Data Communications System Using a Dual-Queue Single Server Queuing Model, JACK S. SYKES, *Bell Telephone Laboratories, Holmdel, New Jersey.*

A non-priority, single-server queuing system has been analyzed in which two queues are alternately serviced. Each queue is assumed to have an independent Poisson input and an arbitrarily and independently selected service time distribution. The distribution of the intervals required to switch from one queue to the other may also be arbitrarily and independently chosen for each queue. All units entering a queue while that queue is being serviced are served in order of their arrival until the queue is empty. No limit is placed on the length of either queue. The following aspects of the steady-state solution are presented: 1. The first four moments of the queue length distribution functions, 2. An approximation to each queue length distribution function, 3. The average rate at which service would be made available to a queue, 4. The average delay of a unit entering the system. The model has been applied to a generalized data communications system in which transmission between two data stations is possible in only one direction at a time. An estimate is obtained of the message storage requirements at each data station as well as the average delay of messages to be transmitted from one station to the other.

FA5.3 Waiting Time Between Events for Superimposed Renewal Processes, S. BLUMENTHAL, J. A. GREENWOOD and L. HERBACH, *New York University, Department of Industrial Engineering and Operations Research, University Heights, New York, New York.*

For superimposed renewal processes, the distribution of time between events approaches an exponential distribution as both the number N of processes, and the age T of the system of renewal processes increase. Corrections are derived to this limiting distribution which account explicitly for both N and T. The T corrections depend heavily on the renewal densities of the processes, and the N corrections on the hazard function near the origin. For selected shape parameters, these corrections are computed for N common Gamma distributions in order to assess numerically the importance of the system age and size in distorting the exponential limit. It is also possible to obtain corrections to expected waiting times. Further, an examination is made of the nature of the limiting distributions and the correction factors when T is small relative to N so that the exponential limit (as N increases) does not apply. These results would be applicable in studying the sequence of failures of a complex equipment which fails whenever any component fails, or in studying a sequence of pooled outputs of a bank of independent queues.

FA5.4 The Time-Dependent Solution to a Many Server Queue, With Some Implications for Decision-Making, HERBERT S. WINOKUR, JR., *Office of the Assistant Secretary of Defense (Systems Analysis), The Pentagon, Washington, D.C.*, and LAWRENCE J. GOLDSTEIN, *Yale University, New Haven, Connecticut.*

A multi-server queue is considered, in which no arrivals are permitted once service has begun. The time-dependent distribution and moments of the number served are calculated. Both exponential and Erlangian service distributions are considered. Tradeoffs between the mean service time and the number of servers can be developed for specific objectives of queue behavior. Definition of cost functions can be used to define optimal service parameters.

FA5.5 A Numerical Inversion of the Pollaczek-Khintchine Formula, CHARLES E. SKINNER, *International Business Machines Corporation, Post Office Box 390, Building 850, Poughkeepsie, New York.*

This paper describes an algorithm which gives upper and lower bounds that can be sharpened to an arbitrarily high degree of accuracy, for the percentage of customers who have a waiting time of t or less for any given t in a single server queue with Poisson input, general service time, and first come first served service order. The algorithm can be modified slightly to yield the same information about the queueing time (waiting time plus service time). Iterating on the answer produces bounds for the maximum input rate such that a given percentage can be accommodated in a given time.

FA5.6 Markovian Queues with Heterogeneous Servers, VIJENDRA PAL SINGH, *Case Western Reserve University, Cleveland, Ohio.*

An $M/M_i/s$ queuing system i.e. a multiple server queue under the assumption of Poisson arrivals and negative exponentially distributed service times with different service rates μ_i for each server has been considered. The service rates are ordered in a decreasing sequence e.g., μ_1 corresponds to the fastest server, μ_2 to the second fastest etc., and a new arriving customer finding more than one server free chooses for his service the fastest one. Explicit steady state and transient solutions for three servers have been given along with some queue characteristics (e.g., average queue length and waiting time, etc.) of the $M/M_i/s$ system. By replacing the service rate for each server in the homogeneous system $M/M/s$ by the average service rate of the heterogeneous system $M/M_i/s$, the two systems $M/M/s$ and $M/M_i/s$ ($s = 2, 3$) have been compared. Conditions have been obtained under which the heterogeneous system $M/M_i/s$ is better than the corresponding homogeneous system $M/M/s$ ($s = 2, 3$). A condition showing the efficiency of $M/M_i/2$ system where customers arriving to find both servers free choose them with probabilities π_i has also been given. In $M/M_i/2$ system, the capacity of the slower channel has been determined and an exact formula has been obtained which gives the best allocation of the service rates to the two channels. Tables and graphs for $M/M_i/s$ and $M/M/s$ ($s = 2, 3$) systems comparing the probabilities of no units, one and two units in the systems have been given.

FA5.7 Approximate Spares Optimization for Complex Systems, S. J. AMSTER, *Bell Telephone Laboratories, Whippany, New Jersey.*

In this paper an intuitively appealing spares optimization criterion will be analyzed and shown to be computationally simple, to yield spares allocations very close (if not identical) to the optimal in the series case and to be readily extended to more complex system configurations. In addition, for an arbitrary system structure, a bound is given between the system performance measure obtainable from the allocation of a single spare by the method and that from any alternative allocation having no greater cost.

FA5.8 A Sufficient Condition for Partial Control of Linear Inventory Systems, S. M. KIM and D. J. WILDE, *Stanford University, Stanford, California.*

Many problems of inventory management are caused by having more storage levels to supervise than there are production rates for changing inventories, a situation known as "partial controllability." This article shows under what condition all levels can be held within predetermined limits, despite random disturbances. Based on this sufficient condition, control law which maximizes the probability of satisfactory operation is developed. A method is given for determining whether a given set of levels satisfies the above sufficient condition. An example is used to demonstrate how the optimal probability control law is implemented.

FA5.9 Inventory Control of By-Products, RICHARD V. EVANS, *Case Western Reserve University, Cleveland, Ohio.*

This system to be controlled produces n products simultaneously in fixed proportions every time it is activated. Demands for the products in any period are components of an n dimensional vector random variable with known distribution function. Cases of excess demands backlogged and excess demands lost are considered. In the former the notion of k convexity can be generalized to guarantee relatively simple form for the optimal policy in an n decision problem. In the latter this generalization was not successful although when there is no setup cost, a convexity argument can be used to show that the optimal policy has a simple form.

FA5.10 Optimal Ordering Policies for a Continuous Time, Deterministic Inventory Model, CHARLES H FALKNER, *University of Wisconsin, Madison, Wisconsin.*

A deterministic, continuous time, nonstationary inventory model is formulated to find the number of orders, the order quantities, and the times at which orders should be placed which minimize the total cost over a finite time horizon of meeting a given requirements function. Both backlogging and no backlogging are considered. Conditions are given for the existence of an optimal policy with a regeneration point property which permits the order quantities to be calculated from the requirements function. The conditions for an optimal policy permit the use of a purchase cost function providing for quantity discounts. Two examples are considered.

FA5.11 Finite-Horizon Multiproduct Inventory Models with Set-Up Costs, ALAN C. WHEELER, *Washington University, St. Louis, Missouri.*

The multiproduct version of the (s, S) stochastic inventory model with periodic review is investigated when the one-period expected cost function is quasi-convex and continuous. It is shown that every finite-horizon problem has an optimal (sigma, $S(x)$) policy, characterized by sets sigma of inventory levels from which orders are placed and functions $S(x)$ determining the levels after ordering. Because of the generality of such a policy conditions are given which ensure optimality of policies with stronger characterizations, i.e., each sigma and $S(x)$ have a more specific form. Examples are given, however, which demonstrate that there need not be optimal policies as strongly and simply characterized as one-product (s, S) policies.

FA6.1 Capital Constraints in Bank Optimization Models, CHARLES W. HALEY, *University of Washington, Seattle, Washington.*

The problem of measuring capital requirements for a commercial bank has been of little interest to other than bank supervisory authorities and specialists in banking and bank policy. The author argues that this state of affairs should not persist. The concept of "capital adequacy" has serious implications for the recent attempts to develop normative models of bank operations. The author suggests that the capital function used in such models essentially determines the policy recommendations derived from them. Furthermore, systems of capital evaluation now in use have little or no theoretical foundation. At present we do not know whether capital adequacy is a meaningful concept, given the usual assumptions underlying normative models. Until this issue is resolved, the results of research on banking operations are questionable. The author presents preliminary efforts toward developing a theoretical framework for capital requirements. The most comprehensive capital evaluation system developed by bank supervisory authorities is a *simultaneous* measurement of asset risk and financial leverage. Current Theory has little to say about varying the total risks of the assets of the firm and treats the problem of leverage in isolation from considerations of risk. The principal conclusion is that while uncritical use of capital constraints in optimization models may yield non-optimal recommendations, some recognition of capital requirements must be included in any model whose results imply changes in the structure or amount of bank assets and liabilities.

FA6.2 Cash Budgeting: An Analytical Model, YAIR E. ORGLER, *Federal Deposit Insurance Corporation, Washington, D.C.*

A lack of synchronization between cash inflows and outflows raises the need for a cash budget and presents the problem of investing positive net flows and financing negative net flows. In addition to the basic investment-financing issue there are other interrelated decisions such as the payment schedule and the minimal cash balance that directly affect the cash budget. Previous attempts to solve this problem have imposed constraints that limit their application. The purpose of that study is to develop a normative cash budgeting model that is applicable to most business firms. This goal is obtained by deriving a linear programming mode

that is divided into unequal periods and includes all relevant decision variables. The model starts with daily periods and continues with weekly and monthly periods up to a selected horizon, usually one year long. This time division maintains the day-to-day aspect of the problem while reducing the number of periods and variables to a manageable size. Decision variables are divided into four groups: The payment schedule, securities transactions, short-term financing, and the cash balance. The model determines the optimal values of these variables based on an objective function that maximizes the net return from administering the cash budget. Although a certainty assumption is made, inputs are analyzed by sensitivity analysis and the dual model while the effects of uncertainty are further reduced by the unequal time structure of the model. Several examples demonstrate that the model provides a solution to the cash budgeting problem which is applicable to most business firms.

FA6.3 Random Variables, The Time Value of Money and Capital Expenditures, IRWIN W. KABAK and JOEL OWEN, *New York University, 100 Trinity Place, New York.*

One of the prime concerns of management is the proper investment of funds for future needs. Recently, analyses have been published relating to uncertainty in capital investment. Heretofore all analyses have pertained to uncertainty in anticipated cash flows or rate of return. This paper treats the following problem. How much money should be invested at time t_0 at an interest rate of I for a time T such that the probability of the funds required "$K(T)$" exceeding those available "$X(T)$" equals at most p. That is $P(K(T) > X(T) \leqq p$, where $X(T) = X(t_0) \exp((I)(T - t_0))$. The parameters I, T, $X(T)$ and $K(T)$ are taken to be random variables. The theory to solve the stated problem is presented and solutions to certain specific cases are given.

FA6.4 Cross Fertilization in a Return-on-Investment Business Model, ROBERT L. HAMSON, *General Electric Company, Post Office Box 8555, Philadelphia, Pennsylvania.*

Consideration of cross fertilization effects is the major contribution of this business decision model. Thus, when R&D or bidding on Project A enhances the profits of Project B, that extra dollar value is credited to Project A. Calculation of cross fertilization effects allows realistic appraisal of a "buy in" bid because the profitable follow-on potential is considered. Decision information is generated for research fund allocation, bid selection and pricing by a criterion of "return on investment." ROI was chosen because of the critical importance of assets—their magnitude and the length of time they are tied up. The model is expected to evaluate hundreds of business opportunities as a group. Time frame inequalities are corrected by discounting. Cross fertilization factors are carried in the off-diagonal elements of the "bid" and "win" matrices. Data evaluation problems caused by tensor element interdependencies may be reduced by first evaluating the total probability of winning a competition and then budgeting it over the contributing projects. Advantages of the methodology include an explicit criterion, human bias reduction by mathematical detachment, full sensitivity capability, and a detailed display of an orderly management tool.

FA6.5 A Dynamic Sales Call Policy Model, LEONARD M. LODISH and DAVID B. MONTGOMERY, *Massachusetts Institute of Technology, 50 Memorial Drive, Cambridge, Massachusetts,* and FREDERICK E. WEBSTER, JR., *Dartmouth College, Hanover, New Hampshire.*

A model is formulated to analyze the optimum level of sales call effort to allocate to specific prospects. A prospect is described by a vector of descriptor variables. An example of a descriptor variable would be his sales potential. The model is formulated as a stochastic sequential decision process, the main elements of which are the probability that the prospect orders and the probability of his order size conditional upon his ordering. These probabilities are functions of the vector of descriptor variables, previous sales to this prospect, remembered past sales effort, and current period sales effort. A two-dimensional state space dynamic program is used to find the optimal call policy for the prospect given his sales history and remembered sales effort. The implications of the model for sales force size are explored.

FA6.6 The Ex-Dividend Behavior of Common Stock Prices, EDWIN J. ELTON and MARTIN J. GRUBER, *New York University, 100 Trinity Place, New York, New York.*

The ex-dividend behavior of common stock is important for several reasons. First, it affects the optimum timing of sales and purchases of stock. Second, it gives insight into the marginal tax bracket of a firm's stockholders. This, in turn, has implications for optimum dividend policy and the cost of retained earnings. Third, knowledge of the ex-dividend behavior of common stock is a necessary prerequisite for the comparison of cash dividends with other forms of cash disbursement (e.g., stock repurchase). There is a large body of literature which states that the price of a share should, and does, fall by the amount of the dividend on the ex-dividend day because assets per share fall by the amount of the dividend. Yet, the published empirical work on ex-dividend behavior gives some indication that the price might fall by less than the full amount of the cash dividend. We believe that there are sound theoretical reasons why this should occur. The value of a dividend to any stockholder should be equal to the amount of the dividend minus the taxes associated with the payment of the dividend. These taxes are of two types. The stockholder pays an income tax on the amount of the dividend. The stockholder saves capital gains taxes on any fall in price associated with the dividend. Consequently the change in price associated with the payment of a dividend should be equal to the amount of the dividend times the ratio of one minus the stockholders income tax rate to one minus the stockholders capital gains tax rate. We intend to test this theory.

FA6.7 Consumer Behavior Models for the Automotive Market, JAMES E. WALLACE, *General Motors Research Labs, Warren, Michigan,* and RALPH L. MILLER, *General Motors Building, Detroit, Michigan.*

For a number of reasons which will be discussed, consumer preference data is sometimes more relevant to the automotive marketing man than is actual sales performance. From the manufacturer's point of view it is important to be able

to relate overall preference levels to those specific product attributes over which it exercises some control. Several possible models for establishing such a relationship will be presented. Based on almost 75,000 detailed home interviews over a five year period, the effectiveness of these alternative models will be assessed. The results of one particularly promising model will be discussed in some detail, and its implications for design, advertising, and merchandising will be explored.

FA6.8 A Study of Consumers' Cognitive Structure for Cigarette Brands, DAVID KLAHR, *University of Chicago, Chicago, Illinois.*

The purpose of this study is to investigate the cognitive structure of consumers with respect to branded items. We construct a spatial configuration of cigarette brand names. The configuration is obtained by applying a nonmetric multidimensional scaling procedure to a set of judgments about interbrand *similarities*. This configuration is then related to paired comparison *preference* judgments from the same group of smokers. The similarity-based space is consistent with the preferences and can be used to predict the location (and hence the description) of an "ideal" brand. This work is an extension of earlier research on decision making through the use of nonmetric multidimensional scaling. We will discuss the advantages and disadvantages of this approach to the investigation of cognitive structure of consumers.

FA6.9 A Model of Conflict Behavior in Extended Prisoner's Dilemma, GERALD R. MCNICHOLS, *Operations Analysis Office, Hq. U. S. Air Force, Washington, D.C.*

A model developed in this paper examines the decision process involved in playing an infinite two-person N-choice non-zero-sum game in which no communication is allowed except through changes in cell choices by the players. The model involves four basic components of the decision process: *Reception* of information; *Adjustment* of choice probabilities of ultimate tendency of the game to approach one boundary or the other (i.e., cooperation or defection); *Selection* of the appropriate course of action based on the adjusted probabilities; and Interaction of the players in terms of payoff calculations. The model is predictive in nature and has been used to examine the problem of selecting advertising expenditures in a marketing context as well as predicting outcomes in international conflict situations.

FA6.10 A Mathematical Model for Decision-Making in Multistage Marketing Channels, MELVIN F. SHAKUN, *New York University, 100 Trinity Pl., New York, New York.*

Marketing channels are often multistage in character involving, for example, producers, various middlemen and consumers whose decisions are mutually interactive. In this paper, a dynamic model for pricing, dealing and advertising decisions is developed for such a multistage marketing situation. This involves competition among producers who sell brands in a given product class to retailers who in turn compete for consumer sales. The model enables one to treat the type of product class retailers consider to be a "leader." In other words, the retailer

markets the product not only for the profits which its sales generate, but with the intent of attracting the consumer to purchase other products from him (a coupled market effect). Various facets of model building for multistage marketing channels are discussed including game-theory aspects.

FA6.11 A Comparison of Decision Strategies Within a Simulated Oligopolistic Market, HOWARD W. PIFER, *Harvard Graduate School of Business Administration, 6171 Leesburg Pike, Falls Church, Virginia.*

When the environment in which a firm operates is perfectly specified, the objective of the firm (e.g., profitability) is assumed to be synonymous with the strategy employed (e.g., maximization of profits). However, a dichotomy may exist under conditions of uncertainty resulting from a lack of knowledge of the underlying demand phenomena or competitive reactions, or both. The purpose of this research is to compare alternative decisionmaking strategies within a simulated oligopolistic market. The markets to be employed are those provided by two well-known management simulations—the Carnegie Tech Management Game and the UCLA Executive Decision Game. These pedagogical tools will be incorporated within a simulated oligopoly market to observe the interaction of behavioral, economic, and managerial processes. Results indicate that competitive firms with a set of alternative decision strategies may employ different strategies although seeking to attain the same objective. This results from differences in competitive characteristics, such as product cost and market potential, and yields game-theoretic solutions. One of the major unresolved methodological problems associated with simulation experiments is verification. Since the outputs of this study are alternative time series, a regression procedure is applied to test whether these time series are significantly different.

FP1 Panel on: Management Sciences and Health Planning, CHAIRMAN, MARK S. BLUMBERG, M.D., *University of California, Berkeley, California 94720.*

The systems for providing preventive and personal health care services in the United States are being subjected to more systematic and formal planning in an effort to utilize scarce resources effectively. Many believe that systems analysis is readily applicable to planning in the health field while others are less optimistic. The health field has some attributes which make it somewhat different from the commercial and military fields where systems analysis has enjoyed its widest acceptance. For example, the health field is often characterized by inadequate market mechanisms and highly complex relationships between numerous independent government and private organizations. Topics such as the following will be considered by the panelists: procedures currently used to plan health programs; measures of benefits of health programs; adequacy of mathematical and statistical concepts to model health programs; the availability of pertinent data to permit sophisticated health planning; the probable implications of further health planning to the government and private sectors; and the professional background desirable

for future health planners. Specific examples will be given of opportunities and problems in applying management science techniques to health planning.

FP2.1 *An Appraisal of Some Shortest Path Algorithms, S. E. DREYFUS, *University of California, Berkeley, California.*

Several traditional problems involving the determination of shortest paths through discrete networks will be examined. To avoid special cases, it will generally be assumed that all nodes are directly connected to all other nodes. Good algorithms will be identified and credited, to the best of the speaker's knowledge, to their earliest originators. Also some erroneous or inefficient procedures will be exposed. While little new material is developed, it is hoped that the talk will shorten some listener's paths through the shortest path literature.

FP2.2 *Finding a Cycle with Minimum Cost to Time Ratio in a Graph, GEORGE B. DANTZIG, *Stanford University, Stanford, California,* WILLIAM BLATTNER and M. R. RAO, *U.S. Steel Corporation, Monroeville, Pa.*

One can reduce this problem to finding an extreme optimal solution of a linear program. The simplex procedure can be interpreted as seeking the shortest routes from an arbitrary node to all other nodes using as adjusted arc costs the original arc costs less the product of the arc times the ratio of some cycle. If all shortest routes are found the cycle is optimal; if a negative cycle is found, the latter will be an improving cycle. It will be shown that the optimal scheduling of boats for shipping cargo between ports can be solved by the decomposition principle where the subproblem is one of finding a cycle with minimum cost to time ratio.

FP2.3 *An Urban Transportation Simulation, L. R. FORD, JR. and W. H. JAGO, *General Research Corporation, Santa Barbara, California.*

An Urban Transportation Simulation, including both public transit and private vehicles, coded for a CDC3600, is described. It has been applied to several U.S. cities (e.g. Boston), in time periods out to 1990, to evaluate certain cost/benefit measures of various present and future transportation systems in various mixes. The basic algorithm is a "shortest chain" combined with a global iteration, with capacity constraints introduced to speed convergence.

FP2.4 *An Entropy Minimizing Traffic Distribution Model, ROBERT M. OLIVER, *University of California, Berkeley, California.*

Traffic distribution models are used to predict the traffic flow from zone i to zone j given supply and demand data at each zone in a large geographical region. In this paper the author discusses an entropy minimizing traffic distribution model of the form

$$\operatorname*{Min}_{f_{ij} \geqq 0} \sum_{ij} (f_{ij} \ln f_{ij} + \gamma c_{ij} f_{ij})$$

subject to conservation of flow at each zone. It will be shown how the solution of this problem is related to a class of matrix scaling problems studied by Sinkhorn

and how the flows predicted by such a model compare with experimental values obtained in a nine-zone network of the San Francisco Bay Region.

FP2.5 *Substitution Properties of Network Flows, EDWARD IGNALL, *Department of Industrial and Management Engineering, Columbia University, New York, New York,* and ARTHUR F. VEINOTT, JR., *Department of Operations Rseearch, Stanford University, Stanford, California.*

The out-of-kilter algorithm is applied to establish substitution properties of optimal flows in certain networks. By this is meant that increasing the upper or lower bound of certain variables causes the optimal values of certain other variables to decrease.

FP2.6 A Multiperiod Transportation Problem With Stochastic Demands, W. D. EKLOF and G. L. NEMHAUSER, *The Johns Hopkins University, Baltimore, Maryland.*

A dynamic version of the transportation (Hitchcock) problem is considered. There are demands at each of n sinks for T periods which are fulfilled by shipments from m sources. A requirement in period t_2 can be satisfied by a shipment in the same period (a linear shipping cost is incurred) or by a shipment in period $t_1 < t_2$ (in addition to the linear shipping cost a linear inventory cost is incurred for every period in which the commodity is stored). A well-known method for solving this problem is to transform it into an equivalent single period problem with mT sources and nT sinks. Our approach treats the model as Tm source $- n$ sink problems linked together by inventory variables. An extension of the Ford-Fulkerson primal-dual algorithm is developed that takes advantage of the multistage transportation structure. This allows us to: 1. Solve larger problems (or use a smaller computer) than would be possible using the single period equivalent. 2. Incorporate upper bounds on inventories that can be carried at sources and/or sinks (to do this in the single period format requires constraints on partial row and column sums) 3. Solve a chance-constrained model with stochastic demands.

FP2.7 A Graphical Interpretation of the Multi-index Transportation Problem, P. M. GHARE, *Virginia Polytechnic Institute, Blacksburg, Virginia*

The multi-index transportation problem is described as a bi-partite graph. A pseudo-flow function is defined for each arc and every feasible finite pseudo-flow is shown to correspond to a feasible, finite solution to the multi-index transportation problem. The necessary and sufficient conditions are derived for the existence of a feasible finite pseudo-flow.

FP3.1 On the Theory of Cost-Benefit Analysis, CARL R. JONES, *Code 55Js Department of Operations Analysis, Naval Postgraduate School, Monterey California.*

This paper is a contribution to the theory of cost-benefit analysis. The model presented here synthesizes and extends various previous models of cost, effectiveness, and production. It utilizes the Kuhn-Tucker theorem. The model describes the structure of the decision problem faced by governmental management where cost-benefit analyses are used. The decision maker's "value judgments" are first

analyzed and the model structured to incorporate the various senses in which "value judgment" is used. The model also contains the flexibility to discuss multiple measures of cost, methods of forecasting and measures of benefit. In addition, multiple scenarios are discussed and incorporated into the model. An overall criterion of efficiency is discussed and assumed. The model is then used to derive the decision rules for efficient generation of costs and benefits as a vector. Expenditure ceilings (budgets) are included in one variant and not in another. These decision rules show that many of the rules or principles usually stated are inaccurate or at least rather misleading. The decision maker's preferences are used to discuss the nature of final choice from the efficient set. A sensitivity study of the final decision to the model's parameters is given.

FP3.2 A Cost-Production Model of a USAEC Isotope Production Facility: Use in Cost Effectiveness Studies, S. V. Topp, *Advanced Operational Planning, Atomic Energy Division, E. I. du Pont de Nemours & Co., Aiken, South Carolina*

A computer model has been developed to calculate operating modes, costs, and requirements for scarce materials as a consequence of widely varying radioactive isotope demands on the nuclear reactors at the Savannah River site (operated for the USAEC by E. I. du Pont de Nemours & Co.). Operating modes to meet certain product requirements while maximizing the production of other desirable products are calculated, as are fixed and variable costs and capital requirements. The model is used in cost effectiveness studies of net return or special product unit cost based on product unit values under conditions of uncertain product values. The interaction of this model with others to form an optimization technique for the complete USAEC isotope production complex and a simplified version of the model for locating broad regions of near optimum operation are discussed. A description is given of the evolution of the model into a tool useful in forecasting actual budgets and plant operating schedules.

FP3.3 A Cost-Effectiveness Approach to Facilities Layout, Roy D. Harris and Roland K. Smith, *The University of Texas, Austin, Texas.*

The purpose of this paper is to propose a general approach for the analysis of alternative layout designs. It is hoped that this approach will provide a methodology which may be used by industrial firms in their analytical process of evaluating the potential value and applicability of proposed facilities-configuration situations. Specifically, the purposes of this paper are (1) to briefly explore the general area of production design essential for a background understanding of plant layout; (2) to suggest a systems approach to the facilities configuration problem; and (3) to suggest a cost-effectiveness methodology for evaluating alternate layout proposals from the systems analysis viewpoint.

FP3.4 R&D Decisions by Cost Effectiveness?, Robert L. Hamson, *General Electric Company, P. O. Box 8555, Philadelphia, Pennsylvania.*

Mission cost effectiveness may be an important criteria for evaluating applied research and development. Thus, R&D tasks could be expanded until their costs

it exert an important impact upon the decision making process. Requirements to quantify worth notions induce decision makers to formulate and validate their preferences. An additional consequence is to provide an explicit and logically consistent assessment structure, which, if considered acceptable, may be used to guide a final decision. The procedure is both general and flexible with respect to type of decision, type of alternative, and type of worth criterion. However, its application may be restricted by type of decision-making personnel and certain contextual factors.

FA4.2 *Benefit-Cost Estimates for the Job Corps, GLEN G. CAIN, *Social Systems Research Institute, University of Wisconsin, Madison, Wisconsin.*

A number of benefit/cost ratios for Job Corps are reported in this paper. Different assumptions about the appropriate concepts and measures of the costs and benefits lead to ratios that range between .60 and 1.89. The interval from 1.02 to 1.70 is suggested as encompassing a set of ratios that are conservative and realistic. An important limitation of this study is that the sole measure of benefits is the improvement in labor market earnings of the Corpsmen. Two sources of data are used for measuring the benefits from Job Corps. One is a report of gains in reading and mathematics by Corpsmen. Existing studies of the relation between earnings and education provide a basis for translating the educational gains into expected future lifetime earnings. The second data source consists of two surveys conducted in February 1967 of: 1) a sample of ex-Corpsmen who left Job Corps during August 1966, and 2) a sample of applicants who were accepted for Job Corps but who did not participate in the program. The latter comprise a group with which the ex-Corpsmen are compared in terms of the median wage rates earned as of the survey date. Using conservative discount rates to translate expected future earnings into present values, the estimated present value of the improvement in lifetime earnings for the *average* Corpsman (*who is in the program about five months*) is between $3,600 and $5,900. The cost figures that are used are comprehensive and measure the different costs of varying average durations in the Job Corps. Nine months is the normal term for graduation, and five months is the estimated average stay for all Corpsmen—graduates and dropouts combined. The net costs of the average Job Corps experience for a youth (again *based on a five-month stay*) is estimated to be about $3,500. Benefit/cost ratios that are larger than unity follow directly.

FA4.3 *The Production Function in the Public Sector: Production of Postal Services in the U.S. Post Office, LEONARD MEREWITZ, *Department of Economics, University of California, Berkeley, California.*

The objective is to measure efficiency in the operation of remote offices and to estimate production functions for post offices. Such a method for evaluating efficiency in other government activities may be practical with data forthcoming from PPBS studies. A quasi-concave programming problem is defined in which post offices are assumed to try to minimize cost subject to output constraints. A generalized Cobb-Douglas model is used here with factor prices and outputs varying cross-sectionally over 160 U.S. cities. A Post Office norm is estimated econo-

metrically from a subset of efficient offices. Other offices can be compared with this norm and directed to emulate those with efficient factor proportions. Returns to scale can be studied and an optimal size of office suggested. Recent work in the theory of multiproduct production correspondence suggests that a Cobb-Douglas formulation is inadequate for its assumed hypersubstitutability among factors and its perverse convexity in output space. The fruitful direction is to specify reasonable cost functions rather than production functions and make use of the duality between these two.

FA4.4 *An Optimal Allocation of Resources for the Capital Budgeting Problem, JOSEPH J. MODER, *Department of Industrial Engineering, University of Miami, Coral Gables, Florida,* and JAMES J. NICKL, *Lockheed Aircraft Corporation, Burbank, California.*

As the channels to which money can be allocated become greater in number, and their interrelationships become more complex, a systematic approach to budgetary decision making becomes essential. Such an approach is developed in this paper, assuming that the program under consideration has a fixed sum of money for allocation, which is insufficient to finance all of the alternative activities under consideration. A sequential procedure, utilizing the PPBS approach, is developed to evaluate the comparative worth of interacting alternatives in the capital budgeting analysis, and to maximize their combined benefit or effectiveness. While certain mathematical techniques are incorporated in the model, the general mathematical intractability of this problem is recognized. The need for open discussion, subjective opinion, intuitive insight and competitive bargaining are essential ingredients in the proposed systematic procedure. The mathematical formulations are designed to be an aid to the intellectual and experiential capabilities of the individuals involved in the study. Some applications of this procedure, especially in the context of Model Cities Planning, will also be presented.

FA4.5 A Cost-Effectiveness Framework for Urban Transportation Plan Evaluation, JOSEPH L. SCHOFER, *Department of Systems Engineering, University of Illinois at Chicago Circle, Chicago, Illinois.*

This paper presents a generalized strategy for the application of cost-effectiveness analysis to the evaluation of urban transportation plans. The structure of the cost-effectiveness approach is described, and the major differences between the proposed methodology and traditional benefit-cost analysis are discussed. These differences are shown to result in the considerable advantage which cost-effectiveness presents over the more common evaluation techniques. This is particularly true in cases where social, psychological, aesthetic, or other consequences of alternative plans result in many intangible or incommensurable factors which must be considered in the decision process. A generalized model of system effectiveness based on a conceptual model of the transportation system and its interface with its environment, as well as on unique local objectives, is presented. Several hypothetical examples are then introduced to illustrate the application of the proposed methodology to operational transportation planning processes.

are equated at the margin to the discounted gross savings expected over the system life. Methodology: (1) Identify the best present R&D plan. (2) Name important variables. (3) Define a decreasing marginal returns curve for one variable (a three parameter approximation is shown) by estimating costs and results of more expensive and less expensive R&D plans. (4) Obtain a refinement of original plan by computing the variable level causing greatest savings. (5) Continue sequential refinement by working each variable several times until savings improvement equals iteration cycle cost. (6) Monitor actual costs and results during execution of resulting "optimum" plan for real time adjustment in R&D expenditure. Advantages include an explicit criterion, consistent integration of data, human bias reduction by mathematical detachment, required consideration of alternatives and a detailed display of decision methodology. The sensitivity of results to all parameters and data is displayed. Discussion includes budgetary fragmentation as a major roadblock to R&D optimization.

FP3.5 A Cost-Effectiveness Approach to Urban Air Pollution Abatement. ELLISON S. BURTON, SAMUEL R. PETERKIN and WILLIAM SANJOUR, *Ernst & Ernst, 900 17th St., N.W., Washington, D.C.*

Urban air pollution is a complex phenomenon involving the interaction of area meteorology with hundreds of sources of pollutant emissions. In general, a source emits several pollutants and there can be many technical alternatives for control of each pollutant. The cost of these alternatives varies depending on size and efficiency in the case of hardware, and on usage and availability in the case of fuels. The achievement of air quality goals for the area can be stated in terms of pollutant emissions, ambient air concentrations, or measures of exposure. A practical computerized model will be described which determines the source-by-source costs for achieving stated air quality goals under different constrained-cost strategies. Applications of the model to both hypothetical and real cities will be summarized.

FP3.6 Methodology for Measures of Effectiveness, JEROME A. STEMBER, *Hughes Aircraft Company, Culver City, California.*

The primary purpose of effectiveness evaluation of military systems is to provide a basis for the comparison of candidate system designs. The major difference between effectiveness evaluation and other types of comparison is the fact that this methodology enables the examination of system performance in an operational environment. This comparison becomes a powerful evaluation tool when it brings all significant operational and environmental parameters to bear on system performance so as to reflect the way in which the system performs its design objectives. The inputs to this evaluation consist mainly of weapon system performance characteristics and elements of the conflict situation in which the system is expected to perform. The methodology to be presented in this paper shows how a set of sortie effectiveness submodels may be combined in such a manner as to reflect the sensitivity of an air-to-surface weapon system design to the time urgency conditions under which sorties must be staged. This takes into consideration factors such as target type, quantity and lifetime, local and area enemy defenses, and the array of light and weather conditions characteristic of the area of the world in

which the conflict occurs. The outputs of this process represent a set of "figures-of-merit" by which management may intelligently rank alternative weapon system designs and contributes strongly to the weapon system selection process.

FP3.7 A Methodology for the Measurement of Complex Organizational Learning Processes, MARTIN PFAFF, *Michigan State University, East Lansing, Michigan.*

This paper reports on the development and application of a methodology for the measurement of complex organizational learning processes. The application of this methodology gave rise to a theory of organizational learning that differs from—and at the same time synthesizes—the two dominant types of theories in vogue, that is the smoothly-incremental learning-curve theory and the opposing theory claiming "fits and jumps" as characteristic of organizational learning behavior. The methodology employed for the measurement of organizational effectiveness was developed for the analysis of man-computer simulation experiments and involved the following steps: (A) The reconstruction for all basic units of time of the total set of messages (equal to communication stimuli) and of the total set of acts (equal to control behavior responses). (B) The use of statistical inferences to reconstruct the properties of the generating stationary process for establishing patterns of relationships between subsets of stimuli and subsets of responses. The use of multiple regression analysis and related partial correlation techniques gave rise to *average* relationships only. Spectral and cross-spectral analysis, however, made possible the description and prediction of oscillatory learning processes. What appears as "fits and jumps" to the untrained eye may be resolved into sets of superimposed oscillatory curves. The analysis of organizational learning processes by the methods described, suggests that the "thesis" of smoothly incremental and the "antithesis" of irregular learning processes find their "synthesis" in sets of simultaneous oscillatory patterns.

FP3.8 A Heuristic Compromise between Probability of Success and Limited Resources, MURRAY TUROFF, *Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia 22202.*

This paper proposes an analytical technique for modeling by the analyst of a particular decision situation. Evidence supporting the basic proposal, properties of the technique, discussions of its possible applications, and examples are also presented. The basic problem is a compromise between the probability of success in a single trial versus the total expected number of successes over many trials under the constraint of a limited and uncertain resource. The analogous situation of choosing an operating point for a system which is a compromise between the effectiveness of the system and its efficiency (effectiveness divided by cost) is also discussed.

FP3.9 Towards An Understanding of Network Cost Model Characteristics and Classifications, STANTON E. MINTZ, *Litton Systems, Inc., Van Nuys, California.*

The purpose of this paper is to present the characteristics of each cost model. This will provide the reader with a method of classifying and identifying each

model. The need for being able to identify the various cost models or their mutations is becoming more evident in a climate which is literally spawning multi-named time cost systems. The ability to identify a distinct class or model will aid in determining its utility, as each model has certain input-output characteristics which limit the scope of its application. These input-output characteristics will be summarized. The utility and limitations of each model will also be presented.

FP3.10 Integrating Productivity Measurement with Resource Allocation Through Linear Programming, RUSSELL W. FENSKE, *University of Wisconsin-Milwaukee, Milwaukee, Wisconsin.*

The product mix problem normally solved by the simplex or other standard linear programming algorithms can be improved considerably in simulating actual production situations if productivity measurement methods and techniques are incorporated. Conventional linear programming assumes that the quantity of product produced is directly proportional to the quantity of a productive resource utilized although in many cases this is entirely unrealistic. Furthermore resource constraints are treated independently although economists have long recognized that there is an area of "rational factor use." Finally linear programming treats all resources with equal emphasis although the most critical in most operations are the "productive" resources i.e. labor, equipment, and energy. Although linear programming is a decision making tool and productivity is a measuring device for comparing performances, the former can benefit greatly from the concepts of partial productivities. This paper will review some of the partial productivity measurement techniques, the area of rational factor use, and productive factor limitations. A model will be constructed based on productivity considerations and modified with resource allocation conditions. This model although a true resource allocation rather than demand satisfaction model (as are most linear programming applications) will be shown to be a modified version of the conventional product mix model.

FP3.11 Mathematical Programming in Institutional Menu Planning, RONALD L. GUE, *Southern Methodist University, Dallas, Texas.*

The paper is a review of research undertaken during the past four years in planning institutional menus. Models discussed will include those of regular and therapeutic diets. The daily sequential dependencies among diets and menu items are modeled. The problems formulated are deterministic and stochastic zero one programming problems with a multiple choice structure. The size of the problems ranges from 14 to 300 constraints and 300 to 6000 variables. The sequential relationships among diets causes the problem to be decomposable. The effect of a decomposition algorithm on machine time, core and disk storage will be reviewed. Several algorithms for solving various forms of the problem will be summarized. Finally, the practical value of the research will be assessed from implementation results.

FP4.1 Solution of Least Squares Problems by Linear Programming, WILLIAM F. WALKER, JR., *First National City Bank, 399 Park Avenue, New York, New York.*

Linear programming is applied to the classical least squares regression analysis problem and to some related generalizations and extensions. The classical least squares problem is solved using the primal procedure of a typical linear programming code. Least squares problems of "full rank" and "not of full rank" constrained least squares problems are also solved using a linear programming primal procedure. Finally let yi and $\hat{y}i (i = 1, 2, \cdots, m)$ represent the actual and forecasted responses respectively, and the following two problems are solved using primal, dual and parametric linear programming procedures: i) min $\sum_{i=1}^{m} | yi - \hat{y}i |$ and ii) min $(\max_i | yi - \hat{y}i |)$.

FP4.2 Errors in the Variables with Inconstant Variances, BENJAMIN KING, *Graduate School of Business, University of Chicago, Chicago, Illinois.*

The problem of estimating the parameters of a functional relation between two variables when both of the variables are observed with error has been covered extensively in the literature. It is well known that conventional least squares procedures lead to biased estimates. A situation that is seldom discussed, however, is that where the error variances are not constant from observation to observation. Through a sequence of Monte Carlo experiments this paper examines the behavior of conventional as well as unconventional estimators for small sample sizes in cases where error variances are inhomogeneous. Emphasis is laid on the pervasiveness of this type of problem in management science with examples including a hypothesized functional relation between the mean and the variance of a Normal process.

FP4.3 An Application of the Sampling Theorem of Information Theory to the Reconstruction of Time Series, D. BOYANOVITCH, *Morgan Guaranty Trust Company of New York, 23 Wall Street, New York City.*

Many economic time series suffer from a lack of observable data. For example, observations are obtained on a semi-annual or quarterly basis, whereas it is desirable to have monthly or even weekly data. This paper presents a method which can be used to estimate, say monthly data, given known quarterly data. The method borrows heavily from information theory and uses an appropriate "anchor" time series, i.e., a series about which more information is known, to generate the missing monthly (or weekly) observations of the required series. This method was run in competition with the linear regression technique and preliminary results indicate that the former yields consistently better estimates than the latter. As an illustration, an estimation test was carried out on a class of problems which arose in the evaluation of performance of pension trust funds.

FP4.4 Using Evolutionary Spectra for Forecasting Seasonal Time Series, AMBAR G. RAO and ARTHUR SHAPIRO, *Mobil Oil Corporation, 150 East 42nd Street, New York, New York.*

In a previous paper (presented at the 32nd National ORSA meeting) a procedure for adaptive smoothing of time series using evolutionary spectra was proposed. In most cases evolutionary use of the various components of the spectrum as the mechanism for adaptively changing the value of the smoothing coefficient

was superior to schemes using the tracking signal. In addition, the spectral method automatically indicated the nature of the change (e.g. ramp, step, or spike) in the underlying stochastic process generating the time series. The present paper extends the spectral procedure to more complicated time series, such as those exhibiting seasonality or trend. The small variance of spectral estimates together with their sensitivity to changes in the underlying process, make it likely that the proposed scheme will be superior to those using the tracking signal.

FP4.5 Adaptive Forecasting with General Exponential Smoothing and a Related Experimental Design for Sensitivity Analysis, BULENT BAYRAKTAR, *Sinclair Oil Corporation, 600 Fifth Avenue, New York City, New York.*

In order to schedule product shipments to and from terminals an oil company must have fairly accurate figures of expected product movements. A forecasting system is designed based on R. G. Brown's one parameter general exponential smoothing approach. The advantage of this method lies in the simplicity and ability to consider various mathematical models that underlie the behavior of data. Two computer programs are required: The first program generates the desired model for a α-Smoothing Constant. The second program applies the exponential smoothing technique to the given data with selected models, α-smoothing constant combinations, and associated tracking signals. The adaptive nature of the smoothing constant enables the model to respond to changes in the underlying process rapidly. Furthermore, this program can select the best model (i.e., with minimum of the standard deviations of the forecast errors) and report the related statistics. In addition, an experiment is designed to determine the effect of the initial data length, level of data aggregation, α-smoothing constant, and tracking signal on forecast errors. This experiment considers terminals, product groups, data length, level of data aggregation, fitting functions, α-smoothing constant, and tracking signal as factors. Two different models are assumed for analysis of variance: 1) Partially nested model where two levels of crossings are considered: (a) terminals and product groups, and (b) all others. Group (b) is nested in Group (a), except that fitting functions can interact with factors of Group (a); 2) Completely crossed model. In both models, second and higher order interactions are confounded with errors.

FP4.6 Graphical Display Algorithms for Multivariate Prediction and Optimization Studies: An Application to the Field of Metals, T. K. PEYSER, *IIT Research Institute, 10 West 35th Street, Chicago, Illinois.*

Parameters influencing various characteristics of iron and steel alloys were explored from a model-building approach. Multivariate regression analysis yielded optimal combinations of data for criteria such as tensile strength. Estimations were made of the degree to which different variables and their interactions contributed to the variance on the criteria. Two algorithms were developed as graphical display supplements to the prediction equations. The first describes the change in the criterion as a function of a single factor and shows linear and quadratic effects. The second algorithm plots a response surface for the interaction between variables for specified values on the criterion. The formulae were used to produce

visual display diagrams by implementing DIALOG, a conversational programming language developed at IIT Research Institute for the UNIVAC 1105 computer and the Electrosketch, a graphical input-output console. Reproducible photographs were taken by a Polaroid-Land camera attachment to the cathode-ray tube display. The statistical approach and the related procedures proved useful in the determination of tolerance limits for shop control and inspection. The techniques seem generalizable to other production processes.

FP4.7 The Application of Multivariate Statistics to Terrain Mapping Problems, A. N. SILVER, *Martin Marietta Corporation, Denver, Colorado.*

A Multivariate statistical model is formulated for obtaining Maximum Likelihood estimates of the coordinates of a particular terrain feature (assuming a Multivariate normal distribution) utilizing sets of independent observations from multiple sensors (with known a priori measuring accuracies) placed in orbiting vehicles. A brief review of selected basic theoretical literature is presented, including the application of Multivariate statistics to coverage and bomb damage assessment problems, as well as citing current pertinent work performed in the areas of data management and automated techniques of analyses relative to photogrammetry, radar mapping (spectral signature identification), pattern recognition, geology, and automatic agricultural crop surveys. Some aspects of data classification into one of several Multivariate normal populations are also discussed within the context of discriminating between specific terrain features. In addition, preliminary effectiveness criteria, such as the maximization of information returned (bits/dollar), are examined to determine optimal sensor configuration and deployment policies.

FP4.8 Approximate Confidence Limits for Complex Systems with Exponential Time until Failure of the Components, J. M. MYHRE, *Claremont Mens College, Claremont, California,* and S. C. SAUNDERS, *Boeing Scientific Research Laboratories, Seattle, Washington.*

The asymptotic distribution of the log-likelihood is shown to provide a method of determining approximate confidence limits for any coherent system when each component has an exponential life with unknown failure rate and data on the performance of each component is provided in the form of number of failures and total operating time. Some computational methods to facilitate the determination of the lower confidence bound at a given level are provided in the important case of a series system. Comparisons are then made between the results of this asymptotic likelihood ratio method and the Bayesian approach which assumes a uniform prior fiducial distribution of the failure rate, obtaining the posterior fiducial distribution of the system reliability using the assumed independence of the prior distribution and the calculus of probabilities.

FP4.9 Approximations to System Reliability Using a Modular Decomposition, LAWRENCE D. BODIN, *IBM Washington Scientific Center, Wheaton, Maryland.*

The exact evaluation of the system reliability of a coherent structure requires first the enumeration of all min path sets or min cut sets in the coherent structure

(analogous to the enumeration of all elementary paths and minimal cuts in a graph) and then the computation of the system reliability as a function defined over the values assigned to these min path sets or min cut sets. Esary and Proschan show that a lower bound to system reliability can be found by enumerating all min cut sets in the coherent structure, connecting the components in each min cut set in parallel, and joining each of these parallel subsystems in series where replicated components are replaced by identical yet independently operating components. A module of a coherent structure is a subset of the basic components of the system which can be treated as a component of the system due to their substructure topology. In this paper, it is shown that a lower bound estimate of system reliability can be derived by decomposing the coherent structure about its modules and applying the Esary Proschan lower bound procedure to each module and then to the resultant coherent structure where each module has been replaced by a single component whose reliability is the Esary Proschan lower bound to that module. This estimate of system reliability is sharper than the estimate of system reliability obtained by utilizing the Esary Proschan procedure on the total system directly. Furthermore, this estimate is computationally more efficient than applying the Esary Proschan procedure to the total system directly since the min cut sets need only be enumerated for each module. Applications of this result to discerning the best modular decomposition of a coherent structure to use for estimating system reliability is given and analogous results for an upper bound to system reliability are stated.

FP4.10 Failure Rate Estimation From Censored Detection Data, GLEN BENZ, *Genge Industries, Inc., Sherman Oaks, California.*

An examination is made of procedures for estimating dormant failure rates when only times of failure detection and last good test are known. One procedure uses an approximation to the maximum likelihood estimate of failure rate as obtained directly from the known times. Two product limit procedures are examined which estimate reliability as a first step in determining failure rate estimates. One of the product limit procedures assumes failure occurs half way between last good test and failure detection while the other adjusts failure detection rates on the basis of a theoretical solution to the convolution equation. The fourth procedure examined fits a parametric curve to the probability of no failure detection and solves the convolution equation for a continuous reliability function and various distributions of times between tests. It is found that parametric methods yield the most reasonable failure rate estimates when only partial distributions are known due to censorship.

FP4.11 Inference From Accelerated Tests When Observations are Obtained From Censored Samples, NOZER D. SINGPURWALLA, *Western Electric Company, Inc., Princeton, New Jersey.*

Suppose that $f(t, \theta)$ is the p.d.f. of the time to failure random variable of a device, under an environment defined by a vector of generalized stresses $\mathbf{S}$. The elements of the vector θ are reparameterized as a function of $\mathbf{S}$ such that $\theta_j = f_j(\mathbf{S}, \mathbf{a}_j)$, where f_j are known functions and the $\mathbf{a}_j$ are unknown. The objective is to predict ϵ_u,

the value of $\boldsymbol{\theta}$ at some low values of the stress, say $\mathbf{S}_u$. Life tests are conducted at k different accelerated values of $\mathbf{S}$, $\mathbf{S}_i$ $(i = 1, 2, \cdots k)$, and point estimates of the elements of $\boldsymbol{\theta}$, $\hat{\theta}_{ji}$ are obtained from item censored samples. These estimates are then used to obtain point and interval estimates of $\mathbf{a}_j$ which in turn are used to make an inference about $\boldsymbol{\theta}_u$. Some problems in obtaining the least squares estimates of $\mathbf{a}_j$ are pointed out in this paper. This is because the error theory assumptions necessary to invoke an application of the Gauss-Markoff theorem are violated. To illustrate this, let us assume that $f(t, \theta) = \lambda e^{-\lambda t}$, and that $\lambda_i = BV_i$, where λ_i is the hazard rate under an environment V_i, and B is unknown. $\hat{\lambda}_i$ an estimate of λ_i obtained from censored samples has an inverted gamma distribution and its variance for different values of V_i is hetroseacestic. Consequently, a weighted least squares estimator for B is obtained and it is shown that asymptotically this estimator converges in distribution to a unit normal. Alternately, the m.l.e. for B is also obtained and its exact distribution is an inverted gamma. Either estimate can be used to predict λ_u, at use conditions stress V_u. Properties of the estimator of λ_u are discussed and a generalization of this procedure to more complicated situations is indicated.

FP5.1 Optimal Allocation of Work in Production Line Systems With Variable Operation Times, FREDERICK S. HILLIER, *Stanford University, Stanford, California,* and RONALD W. BOLING, *University of Tennessee, Knoxville, Tennessee.*

This paper formulates a production line system with variable operation times as a system of finite queues in series with exponential or Erlang service time distributions, and then considers the mean output (production) rate of such a system. The effect of unbalancing such a production line (i.e., allocating unequal expected operation times to the respective stations) is investigated. It is found that if the production line has more than two stations, then unbalancing the line in an appropriate way actually can increase its production rate. Because of the large total cost involved in operating a typical production line over its lifetime, this way of improving the efficiency of some production lines by deliberately unbalancing them appears to have considerable practical significance. The mathematical properties of this phenomenon and their implications are explored.

FP5.2 Sequential Batch Scheduling In Multistage, Multichannel Systems, MICHAEL RESH, *Bell Telephone Laboratories, Inc., Holmdel, New Jersey.*

The problem of scheduling customers for service in a multichannel, multistage service system is considered. There are several classes of customers for each of which the statistical properties of its service times at each stage are known. Requests for service arrive independently and randomly from each class. Within each class of customers there is a relatively small proportion that must be admitted to the system as soon as a service request is made, but all other customers may be scheduled for admission at some future time. The scheduling procedure is executed periodically to determine the admission times for all requests received during the current period, given a forecast of future available capacity, which in turn depends on previous scheduling decisions. Two versions of the problem are discussed:

"short run," in which only past decisions and current requests are considered; and "long run," in which the potential effect of future (uncertain) requests and scheduling decisions are also considered. Two criteria are used: minimization of the customers' waiting time and minimization of expected losses from idle time and overtime. The two scheduling problems, one with either criterion, may be formulated as integer nonlinear programs with chance constraints. A sequence of analytic approximations, the validity of which can be supported numerically, reduces the two problems to an integer linear program and to an integer dynamic program, respectively.

FP5.3 TOCOM—An Aid to Decision Making in Selection of an Operating Mode for a Multiproduct Facility under Conditions of Uncertain Product Value, J. W. CROACH, *E. I. du Pont de Nemours & Co., Wilmington, Delaware.*

It is difficult to evlauate the relative merits of many proposed operating modes of a multiproduct facility operating under conditions where product demand is not rigid and product value is uncertain. An algorithm is given that may substantially reduce the number of modes that must be considered and that, for each of the remaining modes, (1) gives the relative product values most favorable for that mode and (2) indicates the range of product values over which that mode will be favored over the others. It is shown that the problem can be expressed in linear programming form. A FORTRAN program (TOCOM) has been written for the solution algorithm and has been applied to analysis of radioactive isotope production facilities of the Division of Production, USAEC. A general formulation of the problem and some typical results are given.

FP5.4 Optimization of a Production System Response with Respect to the Input Characteristics, E. S. BAHARY, R. K. BHATTACHARYYA, *Western Electric Company, Princeton, New Jersey,* and A. N. BAKHRU, *Celanese Corporation, Newark, New Jersey.*

In the first part of the paper, a production system has been characterized in terms of certain parameters that define its response characteristics towards the input information to the system. A demand forecast may be a typical input information. A few examples of the system parameters are the reaction time, saturation level, etc. These parameters, in turn, define certain equivalence classes of input information. An equivalence class is a collection of input information such that, for any piece of information belonging to the class, the decision remains the same because of the limitations imposed by the values of the system parameters. In the second part of the paper an optimization problem has been treated which can be stated as follows: Due to limitations imposed by the values of the system parameters, the decision remains the same over a certain equivalence class. But the profit may be different for different pieces of information belonging to the same class. In other words, there is a certain cost associated with the fact that, due to system limitations, different decisions cannot be taken for different pieces of information in the same class. On the other hand, there is a certain cost in improving the system characteristics such that equivalence classes get narrowed down so as to

make the decision-making more flexible. These two costs have to be balanced against each other. In this paper the above mentioned problem has been analyzed from the control theory standpoint, the optimal strategies are determined, and an illustrative example has been worked out.

FP5.5 A Planning and Control System for Disassembly-Assembly Operations in Meatpacking Plants, ROBERT C. MATTHES, *International Minerals and Chemical Corporation, Skokie, Illinois.*

The vast number of raw material, input-product, output alternatives inherent in meatpacking operations encourages the adoption of mathematical programming techniques for production planning and control. This paper describes an optimizing system which improves the operational performance of meatpacking operations by aiding management in decisions regarding raw material procurement, inventories, labor utilization, product routing, primal conversion, and product mix. The system integrates traditional accounting, engineering and sales data with modern mathematical and statistical techniques to generate decision-guides for planning and control. Three major components of this system are 1) the *Forecasting Subsystem* which uses exponential smoothing, 2) the *Allocation Subsystem* which uses the linear programming technique, and 3) the *Information Retrieval Subsystem* which uses an accounting variance model in conjunction with a supporting automated data processing system. Two types of management reports are generated by the system: 1) A detailed set of planning guides which indicate the most profitable plan for the coming period of operation. 2) A detailed set of performance evaluation reports which compare the mathematically optimal solutions with those actually experienced by management. This system has significantly improved the profit performance of meatpacking plants under actual operating conditions by assisting management in most decisions relating to disassembly-assembly operations. The system has general applicability to most large-sized plants.

FP5.6 An Efficient Algorithm for Multi-Item Scheduling, L. S. LASDON, *Case Western Reserve University, Cleveland, Ohio,* and J. E. MACKEY, *Goodyear Tire and Rubber Company, Akron, Ohio.*

Approximate solution of a large class of resource allocation problems, including multi-item production scheduling, may be obtained via linear programming, as shown by Manne. These programs have an enormous number of columns, and may have many rows as well. Dzielinski and Gomory have applied the Dantzig-Wolfe Decomposition algorithm to ease this difficulty. Although attractive, this approach does not maintain an important integrality property of the program being decomposed. Non-optimal solutions may then not be meaningful. Since, as mentioned, programs with very many columns often have many near-optimal solutions prior to optimality, these limitations can be serious. These difficulties are avoided here by a direct attack on Manne's linear program. The large number of columns is handled by column generation, with the same subproblems obtained as in Dzielinski and Gomory's work.

FP5.7 Analysis of Inventory Cost Parameters in Department Stores, M. D. SEVERSKY, *IBM, Data Processing Division, White Plains, New York.*

The main purpose of maintaining inventory in department stores is to satisfy customer demand. When inventory is depleted, action is initiated for replenishment. The problem, in very general terms, is to determine when and how much to replenish in light of associated cost parameters. The inventory decision variables (e.g., order quantity, order point, etc.) and the outcome variables (e.g., inventory level, number of orders placed, etc.) depend on the cost parameters. The paper examines the difficulties involved in determining some of the cost parameters for a typical representative staple department. A suggested approach, utilizing department store restrictions, is developed.

FP5.8 Computer Job-Shop Simulation Model: A Decision Tool, F. D. KNIGHT and M. M. LUDEMAN, *Savannah River Laboratory, E. I. du Pont de Nemours & Co., Aiken, South Carolina.*

Planning and forecasting are essential for efficient operation of a computer job-shop. In the past, this planning has been based on limited decision-making information. However, with the present large-scale computer systems, a technique is needed for quantitatively evaluating proposed changes in operations (hardware, configuration, operating strategy). This paper presents a simulation model of the computer job-shop as such a quantitative technique. Five main points are discussed: a description of the system modeled, the questions to be answered by the simulation of the system, the design of the simulation trials to be run with the model, the development and use of a performance index for comparing proposed modes of operation and the results obtained. GPSS/360 (General Purpose Simulation System) was used to simulate the system whose principal component is an IEM System/360 Model 65 with 512K core. The simulation experiment was carried out to optimize the performance index, which is a function of job turnaround time, job throughput, idle time, and backlog.

FP5.9 Maintenance Policies in Markovian Multiservice Type Systems, ISRAEL BROSH, *Newark College of Engineering, Newark, New Jersey.*

A system which has customers demanding service from a single service station is observed at equally spaced points in time, indexed by $t = 0, 1, 2, \cdots$. When observed, it is classified as being in one of a finite number of states labeled by $i = 0, 1, \cdots L$ and denotes the number of customers in the system. The probability for an arrival of a customer per period is assumed to be λ. The service station has two alternative ways to perform its service. The probability to finish its service in one period will be μ_k if service type $k = 1, 2$ will be used. A cost $[C_{ik}]$ is imposed on the system for being in state i and using service type k. Cost $[C_3]$ is incurred when a customer arrives at the system, finds it full (in state L) and leaves to get service elsewhere. The implementation of a particular maintenance policy generates a Markov process. By the term maintenance policy, we refer to the partitioning of the state space into two sets; that is, states at which the unit is maintained with service type $k = 1, 2$. The measure of effectiveness for choosing the optimal policy is the expected average cost per observation period over an infinite sequence of system observations. The analysis of the policy space reveals the interrelationship between the different variables and the optimal maintanance policies. The possible policies are classified into two major groups: connected

policies and disconnected policies, and their disposition in relation to the variants of the system becomes the basis for a simple algorithm for choosing the optimum policy to operate the system.

FP5.10 Use of Simulation in Analyzing Optimal Maintenance and Replacement for Motive Systems in Railroad Operations, DONALD F. BLUMBERG, *WOFAC Corporation, Moorestown, New Jersey.*

Major railroads are continually faced with the basic problem of the maintenance of complex equipment and the replacement of major capital items due to wear and obsolescence. This problem is particularly acute with regard to motive power since the railroad locomotive is one of the most complex and expensive elements of the rolling stock. Motive power equipment will fail from time to time, requiring the service of repair crews and facilities to put it back into running order. Certain inspections and maintenance repairs are required by government regulations. Both the possibilities of breakdown and the completion of repairs are variable in occurrence. In addition the impact of both the breakdown and the service loss due to failure and to reduced operating efficiency can be significant with respect to operating costs. Examination of the question of maintenance and replacement of motive power involves a detailed consideration of three major areas of interest: optimal timing of technological replacement of motive power; optimum scheduling of preventive maintenance; and optimum scheduling of maintenance facilities and resources. The question of capital replacement and maintenance of motive power involves consideration of the maintenance cost and its effect on reducing unpredicted failures, the out-of-service due to schedule maintenance, and the option of technological replacement. An analytical tool employing simulation techniques can be applied to analyze these issues in a quantitative, orderly manner to assist in optimizing decisions relative to the matters of maintenance and capital replacement of motive power.

FP5.11 A Simulation Model for the Allocation of Milking Equipment on a Dairy Farm, HARRY M. STRONG, and WARREN H. THOMAS, *State University of New York at Buffalo, Buffalo, New York.*

Analysis of farm management problems has traditionally been left to the intuition and experience of the farm manager. This paper applies Operations Research techniques to assist the manager in making maximum use of this intuition and experience by providing the structure for the analysis of a decision problem. A simulation model has been developed for analyzing the dairy farm milking operation with which one can determine the number of milking machines for a given herd type and milking policy which minimizes the cost for a complete milking operation. It includes manpower costs, equipment costs and costs associated with removing a milking machine from a cow too early or too late. The discussion includes a case study of a typical New York State dairy farm to which this model has been applied and highlights possible applications of this algorithm to manufacturing and maintenance.

Society Affairs

THE ORSA COUNCIL MEETING

The Thirty-second Meeting of the Council of the Operations Research Society of America convened on 31 October, 1 November, and 2 November, 1967, at the Sheraton-Chicago Hotel, Chicago, Illinois, with President John E. Walsh presiding. The following items from the Council Meeting are reported. (Complete minutes can be obtained from the Secretary of ORSA.)

FUTURE ORSA MEETINGS:

No.	Dates	Location	Chairman
33	May 1–3, 1968	San Francisco (joint with TIMS)	ERNEST KOENIGSBERG *Matson Research Corporation* *215 Market Street* *San Francisco, Calif. 94105*
34	November 6–9, 1968	Philadelphia	LEO ROGIN *Air Warfare Research Departn ent* *NADS* *Johnsville, Pennsylvania 18974*
35	June 17–21, 1969	Denver	GEORGE W. MORGENTHALER *The Martin Company* *Box 179* *Denver, Colorado 80201*
36	Fall 1969	Miami, Florida	RICHARD L. PATTERSON *Industrial & Systems Engineering* *University of Florida* *Gainesville, Florida 32601*
37	Spring 1970	Washington, D. C.	
38	Fall 1970	Detroit or Ann Arbor (joint with SSCG)	
39	Spring 1971	Dallas	RONALD L. GUE *Computer Sciences Center* *Southern Methodist University* *Dallas, Texas*
40	Fall 1971	Los Angeles	
41	Spring 1972	New Orleans (joint with AIIE)	

The Secretary announced that the proposed Constitutional Amendment had carried by a vote of 770 to 61; consequently, George E. Kimball becomes the first "Third Past President" to serve on the Council.

EDUCATION COMMITTEE: The brochure on educational opportunities in operations research has been published as a special edition of the *Bulletin*. The

visiting lectureship program has been started, and a proposal has been submitted to the National Science Foundation.

LANCHESTER PRIZE COMMITTEE: The Council approved the award of the Lanchester Prize to Stafford Beers for his book, DECISION AND CONTROL, published by John Wiley & Sons, 1966.

IFORS: The Fifth Triennial International Conference on Operations Research will take place in Venice during June of 1969.*

LONG-RANGE PLANNING COMMITTEE: The Committee has formulated a format for its final report, which it plans to present at the San Francisco Meeting.

HEALTH APPLICATIONS SECTION: This Section plans to sponsor a symposium, to be held during 1968.

NOMINATIONS: The following slate has been announced by the Nominating Committee:

Vice President/President-elect	THOMAS E. CAYWOOD
	THOMAS E. OBERBECK
Secretary	ROBERT E. MACHOL
Treasurer	J. H. MOSS
	KENNETH W. YARNOLD
Council (2 to be elected)	CLINTON J. ANCKER
	JACK R. BORSTING
	CHARLES D. FLAGLE
	MARVIN G. SCHORR

(In addition, as a result of nomination by petition, the following will appear on the ballot: JOANN HAWKES LANGSTON, candidate for Secretary; DAVID S. STOLLER, candidate for Council Member; JOHN HONIG, candidate for Council Member. Biographies and ballots will be mailed to Members separately.)

ORSA MEMBERSHIP: As of 30 September 1967, there were 2,090 Members, 3,668 Associate Members, and 632 Student Associate Members, for a total membership of 6,390.

NEW MEMBERS: The Membership Committee reported its nominees for full membership in the Society. The following were elected by the Council as new Members:

Elected Members at 32nd National Meeting

ANDREW, GARY MARTIN
AVOTS, IVARS
BALINSKI, MICHEL LOUIS
BAXTER, MURRELL JACKSON
BRADLEY, HUGH EDWARD
BULLARD, SPENCER ARDELL
BURCH, JACK J.
CLEVELAND, ROBERT HOLLAND
COLLEY, JOHN LEONARD, JR.
CRANE, FREDRICK LOEFFLER
CUYKENDALL, ROBERT R.
DAYOG, LOU DE VERA
DREW, DONALD RICHARD
DUNLAP, GEORGE H., JR.
DUNNE, MICHAEL CLARENCE
EASTMAN, ROBERT MERRIMAN
ENKE, STEPHEN
FINLEY, DAVID REX
FISHER, GORDON P.
FORD, BYRON M.

* The date for this conference has now been definitely set for the week of 23-29 June.

GLASS, HARVEY
GOLDSCHMIDT, JEROME X.
GROBER, DAVID THEODORE
HAGOPIAN, GREGORY A.
HAWLEY, ROBERT C.
HILTON, HOWARD J.
HOFFMAN, THOMAS RUSSELL
HOLMES, DONALD STUART
IVANESCU, PETRU L.
JANNEY, ELWOOD ABER
JOHNSON, JAMES L.
JUDD, BRYAN LESLIE
LANGSTON, JOANN HAWKES
LIDDELL, CHARLES J., JR.
LLOYD, LARRY DEAN
LYNN, WALTER R.
MANZ, BRUNO JULIUS
MACKAY, JOHN G. I.
MATTHEWS, DAVID WRIGHT
MCGUIRE, MARTIN C.
MONTGOMERY, GERALD THEODORE
OVERTON, GARLAN DEAN
PARNELL, THOMAS ALFRED
ROESLER, WILFRED J.
ROSS, STANLEY E.
SANCHEZ, LUIS R.
SERFOZO, RICHARD FRANK
SHANNON, ROBERT EDWARD
SHYCON, HARVEY NORTON
SLAYSMAN, CLARENCE
SPENCER, JOHN W. H.
TESLER, ALFRED
THOMAS, MICHAEL E.
VARGO, LOUIS G.
WAGGONER, EDWARD ELLIS
WANG, THEODORE JOSEPH
YORK, LEROY J.
WOLFORD, (MRS.) JERRY ZUBER

ROBERT E. MACHOL
Secretary

TREASURER'S REPORT

Holloman AFB, New Mexico
18 January 1968

Following is a statement of Cash Receipts and Disbursements of ORSA for the calendar year 1967. The report of the auditors accompanies this statement. A breakdown into two columns is used, with International Abstracts in Operations Research receiving special consideration. The method of statement is on an explicit cash basis with major obligations listed by note.

THOMAS E. OBERBECK
Treasurer

AUDITOR'S REPORT

The Operations Research Society of America,
Baltimore, Maryland.

We have examined the statement of cash receipts and disbursements of The Operations Reserch Society of America for the year ended December 31, 1967 Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying statement presents fairly the cash receipts and disbursements of The Operations Research Society of America for the year ended December 31, 1967.

LYBRAND, ROSS BROS. & MONTGOMERY

Baltimore, Maryland
January 31, 1968

THE OPERATIONS RESEARCH SOCIETY OF AMERICA STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS

For the year ended December 31, 1967.

	Regular	*International Abstracts in OR*
Receipts:		
Members' dues	$62 824	$16 816
Subscriptions	34 766	15 038
Advertising, less commissions	19 004	
Sales of back issues	1 005	1 595
Interest ($2,297 transferred to IAOR)	2 592	2 993
TRANSPORTATION SCIENCE	10 301	
Royalties	2 826	
Mail list, net	1 991	
Miscellaneous	77	
	135 386	36 442
Disbursements, as annexed	134 581	28 297
Excess of receipts over disbursements	805	8 145
Cash at beginning of year	157 143	19 872
Cash at end of year	$157 948	$28 017
Represented by:		
Petty cash funds	1 455	675
Demand deposits	25 133	27 342
Deposits with federal savings and loan associations and bank	131 360	
	$157 948	$28 017
Portions of the cash balance are reserved as follows:		
Unearned subscriptions:		
Volume 16 (OR) to be issued in 1968	67 000	
Volume 8 (IAOR) to be issued in 1968		18 500
TRANSPORTATION SCIENCE	7 500	
Guarantee to publisher of the Society's series "Publications in Operations Research"	6 000	
Third International Symposium	1 000	
IFORS dues for 1967	1 400	
Unpaid printing and managerial bills	22 000	1 000
	$104 900	$19 500

THE OPERATIONS RESEARCH SOCIETY OF AMERICA

DISBURSEMENTS

For the year ended December 31, 1967

	Regular	*International Abstracts in OR*
Journal printing costs	$55 490	$20 562
Editorial and other expenses	10 460	1 459
Salaries and fees		4 604
Managerial services	16 609	1 275
Bulletin printing	8 132	
IFORS dues for 1966	1 978	
Publications in OR	722	
Third International Symposium	3 997	
TRANSPORTATION SCIENCE	7 592	
Council and officers' expenses (Note)	670	
General society expenses	2 864	
Lanchester prize	1 000	
Supplies, materials, etc.		397
Auditing	750	
Committee expenses (Note)	3 451	
Sections expense (Note)	5 174	
Miscellaneous	204	
Directory printing	11 979	
CBMS dues for 1967	1 000	
Meetings—net	2 509	
Total disbursements	$134 581	$28 297

Note: Details of council and officers' expenses and committee expenses are:

Council and officers' expenses:	
President	498
Vice-president	25
Secretary	122
Treasurer	25
	$670
Committee expenses:	
Membership	74
Prize	629
Sections	84
Education	2 664
	$3 451
Section expenses:	
Military Applications	1 991
Transportation Science	561
Cost Effectiveness	2 542
Health Applications	80
	$5 174

News and Announcements

34th NATIONAL ORSA MEETING

The 34th National Meeting of ORSA will be held in Philadelphia on November 6–9, 1968 at the Sheraton Hotel. The host for the meeting is the Philadelphia section of ORSA. Sessions are being organized relating to applications research in varied fields which will cover the following topics with selected chairman as shown:

Systems Approach to Community Problems, B. Z. PALMER, *Fels Institute, University of Pennsylvania.*

Adaptive Models in Marketing, P. J. ROBINSON, *Marketing Science Institute.*

Information Storage and Retrieval, MRS. MARY HAWES, *Information Systems Leasing Corporation.*

Industrial Sessions

Pharmaceutical, MICHAEL LEYZOREK, *Merck, Rahway, N. J.*

Petroleum, R. A. FRANZOW, *Sun Oil, Philadelphia.*

Chemical, (Chairman to be selected).

Steel, J. C. GRACE, *Bethlehem Steel.*

Aerospace, H. C. SEBRING, *General Electric.*

Workshop in O.R. Applications in Space Operations Management, M. W. LODATA, *Douglas Aircraft.*

Cost Effectiveness Analysis (Multiple sessions), (Chairman to be selected).

Space Science, (Chairman to be selected).

Transportation Science, (Chairman to be selected).

Military and Health, (Chairman to be selected).

Models of the Firm, BRINKLOE, University of Pittsburgh.

Simulation in Gaming and/or When Not to Simulate, STEPHEN LEIBHOLZ, *Analytics.*

New Techniques and New Applications, S. MATTON, *General Electric, Philadelphia, Pa.*

Management Information Systems, (Chairman to be selected).

Finance, JAMES L. BICKSLER, *Ford Motor Company.*

Workshop on Economics in Trade, DR. A. PHILIPS, *University of Pennsylvania.*

Research and Development, HILL, *RAND Corporation.*

Problems of Implementing Complex Industrial Systems, LAURENCE LOCKS, *Eastman Kodak.*

Workshop—O.R. Education, E. NADDOR, *Johns Hopkins University.*

Integer Programming, (Chairman to be selected).

Vietnam Applications, (Chairman to be selected).

Recent O.R. Development in Marketing, P. J. ROBINSON.

O. R. in Social Science, (Chairman to be selected).

Non-linear Programming, (Chairman to be selected).

Literature and Professional Communications for O. R. People, (Chairman to be selected).

Contributed Papers

Submission of contributed papers is encouraged. There will be sessions for contributed papers at the meeting. Papers are being solicited for presentation on subjects related to those of sessions of invited papers or on other subjects believed to be of interest to the membership of the Society. It is expected that papers presented will not have been published, or presented at other meetings.

Papers will be selected for inclusion in the program on the basis of quality of content. Some contributed papers of more than usual interest and quality may be selected for presentation in the appropriate session of invited papers.

Abstracts and titles of papers must be received by May 1, 1968 in order to be considered. Abstracts should conform to the following instructions:

(1) Each abstract is to consist of a single paragraph not exceeding 200 words, without footnotes.
(2) The abstract should contain a heading including title, author's name, professional affiliation, and business address.
(3) Abstracts should be typewritten, double-spaced, and submitted in duplicate.

The author should indicate the session(s) to which his paper pertains, and the visual aid required. All abstracts must be mailed to the Contributed Papers Chairman: MR. STEPHEN LEIBHOLZ *1204 Pheasant Road, Rydal, Pa.*

ORSA members interested in organizing workshops on any topic of sufficient interest to attract more attendees are urged to contact Program Chairman: SIDNEY HESS, *Department of Statistics and Operations Research, University of Pennsylvania, Philadelphia, Pa. 19104.*

In addition, a tutorial is planned for the session.

Committee

The 34th Meeting Committee consists of the following chairmen:

General Chairman—LEO ROGIN, *Air Warfare Research Department, NADC, Johnsville, Pa.*

Meeting Advisor—DEAN LEROY A. BROTHERS, *Drexel Institute of Technology, Philadelphia, Pa.*

Program Chairman—DR. SIDNEY HESS, *Wharton School of Finance, University of Pennsylvania, Philadelphia, Pa.*

Publicity Chairman—LAWRENCE FEIDELMAN, *Auerbach Corporation, 121 N. Broad Street, Philadelphia, Pa.*

Contributed Papers—STEPHEN LEIBHOLZ, *1204 Pheasant Road, Rydal, Pa.*

Arrangements Chairman—LOUIS P. CLARK, *General Electric, Valley Forge, Pa.*

Ex-Office Members—Philadelphia Section

Section Chairman—IRWIN GROSS, *University of Pennsylvania.*

Section Vice Chairman—DJOERD HOEKSTRU, *Frankford Arsenal.*

Special Events—JOHN KETTELLE, *Kettelle Associates, Paoli, Pennsylvania.*

Registration —BERNARD ROSENMAN, *Frankford Arsenal, Bridge and Tacony, Philadelphia, Pa.*
Financial—ROBERT STARK, *Department of Civil Engineering, University of Delaware, Newark, Delaware.*

35th NATIONAL ORSA MEETING

The Thirty-fifth National Meeting of ORSA will be held at the Brown Palace Hotel, Denver, Colorado on June 17–20, 1969. The theme of the meeting will be "Planning Challenges of the 1970's in Space and the Public Domain." The meeting will be a joint one between ORSA and the American Astronautical Society. It is Theme oriented sessions, with invited speakers, will be held on such subjects as the application of OR to Urban Planning, Transportation, Distribution, Military and Commercial problems. In addition, discipline oriented sessions will be held on queuing theory, simulation methods and non-heuristic programming. The ASA will also hold theme oriented sessions on Planning Future Earth Orbiting Missions, Commercial Utilization of Space, Manned and Unmanned E Exploration of Space. The ASA will also hold technical sessions on Space Flight Mechanics, Space Power, Navigation and Guidance. All meetings will be open to members of both societies.

WALSH COMPLETES WORLDWIDE VISITS TO OR SOCIETIES

In his role as President of ORSA, John Walsh has completed official visits to the major operations research societies outside of the United States. The societies of Australia, Great Britain, Greece, India, Japan, Mexico, New Zealand, and Spain were visited during July–August 1967. He met with the Canadian Operational Research Society last November, with individual visits to the Montreal, Ottawa, and Toronto Sections. The societies of Argentina, Chile, Peru, and Uruguay were visited last December–January, and the societies of Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Norway, Sweden, and Switzerland were visited in March–April. He has also met with individual operations researchers in Bolivia, Brazil, Colombia, Ecuador, Finland, Guatemala, Hong Kong, Paraguay, Thailand, and Turkey. The purpose of these visits is to further the development and use of operations research through establishment of closer contacts among practitioners of different countries.

NORTH CAROLINA STATE UNIVERSITY

The Board of Higher Education of the State of North Carolina has granted permission to the Department of Industrial Engineering at North Carolina State University to grant the Doctor of Philosophy degree. The Departmental course offerings and the research interests of the faculty stress three main themes of Industrial Engineering. These focal points are Quantitative Decision Making in the design and operation of systems utilizing Operations Research methodology, Human and Environmental Factors and their impact on systems, and the Production Processes of which systems are composed. The program has been developed es-

pecially to meet the needs and interests of all types of engineers and scientists who wish to enhance their competence in any of these three areas.

The educational philosophy of the Department is to provide the student with maximum flexibility in tailoring a plan of study to meet his own personal desires and professional needs. At the same time, it is recognized that a depth of knowledge and understanding is necessary for successfully completing a Doctorate research program. For additional information concerning admission to the Graduate School, inquiries should be directed to:

Dean of the Graduate School,
104 Peele Hall,
N. C. State University,
Raleigh, North Carolina 27607.

1968—NATIONAL OPERATIONAL RESEARCH CONFERENCE

The 1968 Conference will be held at the University of Edinburgh from Wednesday 25th September–Friday 27th September, 1968 inclusive, and the Committee invite offers of papers to be presented at this Conference.

In the past, Conference has been accused of being inward-looking, and we are hoping to rectify this by making the 1968 Conference much more concerned with the success of the scientific approach of Operational Research and its use by Management, highlighting, where applicable, the cost effectiveness of the Operational Research work. How successful we are in achieving our objective depends on the quality of the papers offered, so if you feel, as the Committee do, that O.R. must make an impact on Management by showing results, please let us have your offers of papers. At this stage we only need very brief outlines and your ideas as to how far the work you are reporting fulfills the above objectives.

At the same time, the more technical aspects of O.R. will not be forgotten, as there will be sessions at which contributed papers, especially from younger members of the Society, will be read. So even if you have nothing to offer in the first category but would still like to offer a paper please let us know. Once again we only need a very brief outline.

Please send details as soon as possible to: A. P. Amiry, *Secretary, 1968 Conference Committee, The United Steel Companies Limited, Cybor House, 1–5, Tapton House Road, Sheffield, England.*

OPERATIONAL RESEARCH IN THE USSR

Alec M. Lee*

Air Canada, Montreal, Quebec, Canada.

Some recent correspondence with Dr. Igor Ushakov in Moscow has brought some news of operational research activities in the USSR that will be of interest to readers of this journal. A brief account follows.

In May of this year the first formal meeting of the Operational Research Section

* The author is President-elect of the International Federation of Operational Research Societies and obtained this information in this capacity; it is reprinted by courtesy of the *Bulletin* of the Canadian Operational Research Society.

of the POPOV Society took place in Moscow under the chairmanship of Dr. Igor Ushakov. At the present time it is intended that this Section, the first official body in the USSR to bear the name "Operational Research," will hold a meeting every year on "Radio Day."

Currently negotiations are in progress for this society to become a member of the International Federation of Operational Research Societies. Although delegates from the USSR have attended the last two conferences of IFORS, in Oslo, Norway, and Cambridge, Massachusetts respectively, they have done so only as observers pending the formation of a national OR society in the Soviet Union.

The POPOV Society, which is made up of about 30 sections, is one of the principal scientific and technical societies in the Soviet Union, to which many thousands of engineers in the fields of electronics and radio technology belong. It is a member of the International Radio Union, and its current President is Dr. Vladimir Siforov, who is an eminent specialist in the field of radio electronics.

At the 23rd session of the POPOV Society in May, 1967, therefore, the Operational Research Section held its first full meeting. During the three days of the conference, twelve papers of Soviet and foreign scientists were presented. The following account of the meeting is extracted from the journal "Radio Technika," No. 10 (1967).

The meeting of the Operational Research Section was opened by the current General Secretary of IFORS, M. Charles Salzmann, President of Centre Français de Recherche Opérationnelle, at the invitation of the POPOV Society. M. Salzmann described the functions of IFORS and the activities of its various members such as the Association Français d'Informatique et de Recherche Opérationnelle, the Canadian Operational Research Society, the Operations Research Society of America and the operational research societies in Japan, Italy, Sweden, India, etc. In particular he described the activities of the French Society, AFIRO. M. Salzmann also discussed the role of the international conferences of IFORS at which are discussed current developments in the theory and applications of operational research. The delegates were particularly interested in the activities of the Centre Français de Recherche Opérationnelle, which is one of the first and most prominent organizations of this type in Europe.

The following papers were presented:

T. P. Basharin, "Queuing systems of mixed type with priorities"

D. D. Vinoretzky, "Non-Markov queuing systems with limited waiting and service times"

E. A. Boulagain, "Markov analysis of imbeded markov chains applied to computer operation"

L. P. Leontiev, "The application of a model of reliability for complex systems"

I. B. Hertzbach, "Analysis of unserviceability by means of controlled stochastic processes"

A. M. Gurevitch and I. C. Neychtadt, "Reliability of complex operational (control) systems"

M. A. Boyarskaya, "Evalutation of serviceability of complex electronic systems"

E. A. Gurvin and B. A. Kozlov, "A method for evaluating the efficiency of redundancy of information systems"

A. N. LEBEDEV, "Application of the PERT method to regulate industrial processes"
A. N. MELIKOV, "Application of the theory of graphs to the synthesis of finite automats"
A. D. KRISILOV and G. A. SENIN, "An algorithm for characteristic selection in geological problems"

COST EFFECTIVENESS SECTION

Listed below are those who have been elected officers of the Cost-Effectiveness Section for the 1967–1968 year beginning October 1. The tellers for the election were James McCullough, Harry Piccariello, and Wilbur Steger.

Chairman: ALFRED BLUMSTEIN
Vice Chairman: JOSEPH A. JOSEPH
Secretary: ARMAND B. WEISS
Treasurer: ROBERT J. BYER
Councilman: HUGH J. MISER

OPERATIONS RESEARCH AROUND THE WORLD MEETINGS FOR 1967

The first meeting, sponsored by the Operations Research Society of Spain, occurred at Madrid during July 28–August 1 and had ten sessions. The second meeting, sponsored by the Operational Research Society of India, occurred at New Delhi during August 7–10 and had sixteen sessions. The third meeting, sponsored by the Operations Research Society of Japan, occurred at Kyoto and Tokyo during August 14–18 and had sixteen sessions. The fourth and final meeting was sponsored by The Institute of Management Sciences, and cosponsored by the Mexican Society of Operations Research. It occurred at Mexico City during August 22–25 and had thirty sessions (plus twenty sessions of TIMS Colleges on August 26).

Collectively, this is the largest operations research conference ever held, with 92 sessions and nearly 1,000 attendees. The Operations Research Around the World Meetings were originated and coordinated by JOHN E. WALSH, who was also Program Chairman for the meetings in Spain, India, and Japan. Tentatively, a second group of Operations Research Around the World Meetings will occur in 1970.

SYSTEMS SCIENCE AND CYBERNETICS CONFERENCE

The Systems Science and Cybernetics Conference, San Francisco, California, October 14–16, 1968. April 15, 1968 is deadline for submission of abstracts to Dr. HUGH MAYS, *Fairchild Semiconductor, 4001 Junipero Serra, Palo Alto, California.*

MILITARY APPLICATIONS SECTION

In its discussions of education in Military Operations research, the MAS Council at its Chicago meeting decided that since the longfelt need for a text in Military OR had not been filled, MAS should stop its passive deploring and do something to encourage the writing of such a text.

As a preliminary to formulating policy in this area, the MAS Council needs to know what texts may already be in process.

If you have a text partly written, or have given serious thought to writing one, please let us know so that we can make our plans in the light of all the facts. I would welcome specific suggestions on what form our encouragement might take—for example, how we might help you.

Write to me at: CLINTON J. ANCKER, JR., *Chairman, Military Applications Section, Operations Research Society of America, 23908 Malibu Knolls Road, Malibu, California 90265.*

OPERATIONAL RESEARCH SOCIETY OF INDIA

Beginning volume 5 OPSEARCH, the Journal of Operational Research Society of India, will be brought out in March, June, September and December each year. The editor's office has now shifted and the correspondence regarding the journal should be addressed to Dr. N. K. Jaiswal, Editor OPSEARCH, Defence Science Laboratory, Delhi-6 (India).

DR. GEORGE E. KIMBALL—OBITUARY

Winchester, Mass., December 6. . . . DR. GEORGE E. KIMBALL, an internationally recognized authority on operations research and chemistry died in Pittsburgh where he was participating as a member of Carnegie-Mellon University's Chemical Department Visiting Committee. He was a Vice President of Arthur D. Little, Inc. and lived in Winchester, a Boston suburb. He was 61 years old.

Dr. KIMBALL pioneered the application of the scientific method and higher mathematics to military and industrial management problems. He was also known for his work on the uses of computers and information systems in industry. During World War II, as a member of the U. S. Navy's Operation Research Group, he was a primary contributor to the development of search theory and techniques that significantly improved the effectiveness of U. S. defenses against German submarines. Twenty-four hours after the nuclear bomb had been dropped on Hiroshima, he and a group headed by PHILIP M. MORSE were called upon by U. S. Secretary of the Navy, JAMES FORRESTAL, to brief the Joint Senate-House Armed Services Committee on its technical and military significance. He was later awarded the Presidential Certificate of Merit for his work during the war.

In 1956, Dr. KIMBALL joined the staff of Arthur D. Little, Inc. as Science Advisor, after having served since 1950 as an active consultant. He was profoundly helpful in the establishment and development there of the first industrial operations research staff in the U.S. He was named vice president of the company in 1961.

During his years with ADL, he continued to do research on matters of military importance. Since 1960, his principal contributions in this field were in anti-submarine warfare where he became known as one of the country's most imaginative thinkers and leading authorities on submarine surveillance.

He was born in Chicago, Illinois, on July 12, 1906. He grew up in New Britain, Connecticut, and graduated from Phillips Exeter Academy in 1924. He was a member of the class of 1928 at Princeton, and the University awarded him a Master's Degree in 1929 and a doctorate in physical chemistry in 1932.

From 1933 to 1935 he was a National Research Fellow in Chemistry at the Massachusetts Institute of Technology (M.I.T.); and in 1935–36, instructor in physics at

Hunter College. From 1936 to 1956, except for a leave of absence for his war work, he was a member of the faculty of Columbia University and was appointed a Professor of Chemistry in 1947. During this period he was also a member of the university committees on biophysics and applied mathematics. With HENRY EYRING and JOHN WALTER, he wrote in 1944 *Quantum Chemistry*, still a standard text. With his Navy colleague, Dr. Morse, he coauthored in 1951 *Methods of Operations Research*, the first book to be published on this subject. From 1956 to 1963, he was a Visiting Professor of Chemistry at M.I.T.

From 1948 to 1952, Dr. KIMBALL served with the Research and Development Board in the Office of the Secretary of Defense as a member of the Panel on Underwater Ordnance and as a consultant to the Planning Division. In 1950 he became one of the original members of the Weapons Systems Evaluation Group (reporting to the Joint Chiefs of Staff), and continued as a consultant to that group until 1952. From 1954 to 1958, Dr. KIMBALL was a member of the Army Scientific Advisory Panel. He was a member of the Scientific Advisory Group of the Army Combat Development Command.

In 1955, he was elected to the National Academy of Sciences. He was a founding member of the Operations Research Society of America, a member of the first Council of that society, and became President in 1964. He was Chairman of the Northeastern Section of the American Chemical Society. He was a Fellow of the American Academy of Arts and Sciences, a member of Phi Beta Kappa, Sigma Xi, the Princeton Club of New York and the Cosmos Club in Washington.

Dr. Kimball was active in community affairs and at one time served as President of the Unitarian Church in Hackensack, New Jersey. In Winchester, he was a member of the standing committee of the Unitarian Church and served in a volunteer capacity on a survey of future school population for the School Committee. He is survived by his wife, the former Alice Hunter; and by four children.

FALL JOINT COMPUTER CONFERENCE

The Technical Program Committee for the 1968 Fall Joint Computer Conference in San Francisco December 9–11 has issued a call for papers.

ROBERT H. GLASER of Computer Usage Development Corp., Palo Alto, Calif., is chairman of the technical program and has posted a general statement advising that contributions are solicited on all aspects of the state-of-the-art in hardware, software, systems and applications.

Authors are encouraged to submit suggestions in a variety of areas of professional activity. Among the classic categories are components and circuits, memories and storage devices, programming languages, operating systems, hybrid and time-sharing systems and scientific and commercial applications of computer arts.

Mr. GLASER has stated that only new papers, heretofore unpublished, will be considered.

Five draft copies of full papers (up to 7500 words) and 100–150 word abstracts are due before May 12. Rough illustrations are requested.

Submission should be directed to the chairman, as follows: ROBERT H. GLASER, *Technical Program Committee Chairman, 1968 Fall Joint Computer Conference, P. O Box 2309, Stanford, Calif. 94305.*

PERSONAL ITEMS

JOSEPH H. ENGEL has joined the Communications Satellite Corporation as Special Assistant to the Technical Vice President.

JOHN E. WALSH has joined the faculty of the Department of Statistics, Southern Methodist University.

ELLIOTT M. FOX has joined Pacific Technical Analysts, Inc. as Vice President, Operations Research, S.E. Asian Operations with offices in Bangkok, Thailand.

BRYCE S. GENZLINGER has joined Banco Credito y Ahorro Ponceno, San Juan, Puerto Rico as Vice President of Planning and Information.

HOWARD J. HILTON has been named Professor of Social Science at Pennsylvania State University.

N. U. PRABHU has been promoted to Professor in the Department of Operations Research, College of Engineering, Cornell University.

RICHARD F. BARTON has been appointed Professor of Management, Department of Management, School of Business Administration, Texas Technological College, Lubbock, Texas.

STEPHEN W. LEIBHOLZ has been appointed Vice President and Technical Director of the Computer Command and Control Company, Philadelphia.

ALBERTO LEON has been appointed Dean of the Engineering Division of the Universidad del Valle, Cali, Colombia.

EDWARD A. SILVER has joined Boston University as Associate Professor of Business Administration.

HOWARD E. HIGBIE, Director of the Strategic Analysis Division at the Center for Naval Analyses (CNA), died at Culpeper Memorial Hospital, Culpeper, Virginia, Wednesday, October 4, at the age of 58. He had suffered a heart attack four days before. Dr. HIGBIE, a staff member of CNA since 1953, had served as a project leader, conducting studies in antisubmarine, anti-air, and nuclear warfare. He had also carried out major analytical assignments with Fleet commands in the Atlantic, Pacific, and Mediterranean. Before joining the Operations Evaluation Group, now a division of CNA, Dr. HIGBIE had been a research engineer at M. W. Kellogg Company and a research fellow in chemistry at the Sugar Foundation of the University of Pittsburgh. Earlier, he had been a research associate at George Washington University, a chemist with the Chemical Warfare Service, and a school teacher in Washington, D. C., and Rocky Ford, Colorado. Dr. HIGBIE was graduated from Eastern State Teachers College, Madison, South Dakota, in 1930, with a Bachelor of Science degree in education. He received a master's degree in chemistry from George Washington University in 1938 and a doctorate in physical chemistry from the University of Pittsburgh in 1949. He was a member of the American Associate for the Advancement of Science, American Chemical Society, Operations Research Society of America, Phi Lambda Upsilon, Scientific Research Society of America, Sigma Pi Sigma and Sigma Xi. Dr. HIGBIE lived with his wife, RUTH, at 7813 Maple Ridge Road, Bethesda, Maryland. In addition to his wife, Dr. HIGBIE is survived by his mother, brother, and three sons.

Supplemental Report

EDUCATIONAL PROGRAMS IN OPERATIONS RESEARCH

The following additional programs have been submitted since the special report of the Education Committee was published (Vol. 15, Supplement 2, Summer, 1967). The Committee would like to publish in future bulletins any programs that have not previously been included or any significant changes in existing programs.

ORSA Education Committee:

RONALD L. GUE
WILLIAM S. JEWELL
JOHN D. C. LITTLE
DAVID A. SCHRADY
MICHAEL E. THOMAS
JACK R. BORSTING (Chairman)

Listing of Institutions

Kansas State University B-196
University of Oklahoma B-200
Oregon State University B-201
University of Houston B-205
Illinois Institute of Technology B-208
The George Washington University B-207
University of Pittsburgh B-210
University of Massachusetts B-215
The University of Wisconsin B-216
Washington University B-220

LISTING OF INSTITUTIONS

Kansas State University

Manhattan, Kansas 66504

Operations research is centered in the Department of Industrial Engineering at Kansas State University.

Inquiries: Dr. Frank Tillman, Head, Department of Industrial Engineering, Kansas State University, Manhattan, Kansas 66504

DEGREES OFFERED

B.S. in Industrial Engineering

M.S. in Industrial Engineering (Major in Human Factors or Operations Research)

Ph.D. in Industrial Engineering (Major in Human Factors or Operations Research)

FACULTY

Primary Operations Research

S. Ashour
L. E. Grosh
C. L. Hwang
E. S. Lee
F. Tillman

Associated with Operations Research

INDUSTRIAL ENGINEERING

J. Clifton
C. Hansen
S. Konz
J. Smaltz

CHEMICAL ENGINEERING

L. E. Erickson
L. T. Fan

CIVIL ENGINEERING

M. L. Funk
R. R. Snell

COURSE OFFERINGS

Primary Operations Research

UNDERGRADUATE

I. E. 441, Engineering Reliability and Quality Assurance I
I. E. 471, Operations Research in Engineering I
I. E. 511, Production and Inventory Control
I. E. 571, Operations Research in Engineering II
I. E. 675, Quantitative Techniques in Industrial Engineering

GRADUATE

I. E. 711, Advanced Production and Inventory Control
I. E. 742, Engineering Reliability and Quality Assurance II
I. E. 771, Advanced Industrial Economy Studies
I. E. 865, Simulation of Industrial and Management Systems
I. E. 873, Industrial Systems Analysis
I. E. 874, Operations Research I
I. E. 875, Operations Research II
I. E. 880, Linear Programming
I. E. 881, Nonlinear Programming
I. E. 883, Dynamic Programming
I. E. 885, Maximum Principle
I. E. 890, Advanced Topics in Operations Research I
I. E. 891, Advanced Topics in Operations Research II
I. E. 892, Graduate Seminar in Industrial Engineering
I. E. 896, Research in Industrial Engineering

Associated with Operations Research

INDUSTRIAL ENGINEERING

I. E. 701, Engineering Administration
I. E. 850, Human Engineering I
I. E. 852, Human Engineering II

COMPUTER SCIENCE

301, Introduction to Algorithmic Processes
302, Computer Organization and Programming
420, Non-Numeric Programming
799, Topics of Computer Science

ECONOMICS

631, Principles of Transportation
686, Business Fluctuations and Forecasting
730, Introduction to Econometrics
740, Managerial Economics
815, Value and Distribution Theory

MATHEMATICS

550, Mathematics for Engineers and Physicists I
551, Mathematics for Engineers and Physicists II
552, Mathematics for Engineers and Physicists III
601, Differential Equations

621, Advanced Calculus I
622, Advanced Calculus II
701, Theory of Matrices I
702, Theory of Matrices II
761, Numerical Methods I
762, Numerical Methods II
763, Numerical Methods III

STATISTICS

610, Theory of Statistics I
611, Theory of Statistics II
620, Statistical Methods I
621, Statistical Methods II
710, Sample Survey Methods
716, Non-parametric Statistics
720, Designing Experiments
735, Linear Models
740, Multivariate Analysis
745, Foundations of Probability
750, Stochastic Processes
770, Intermediate Theory of Statistics I
771, Intermediate Theory of Statistics II

COMMERCE

440, Marketing
600, Business Policy
601, Advanced Management
610, Business Measurement and Forecasting
631, Organizational Behavior and Administration
640, Marketing Analysis

APPLIED MECHANICS

716, Applied Linear Analysis
721, Applied Nonlinear Analysis
870, Transform Calculus Applied to Engineering Problems

CHEMICAL ENGINEERING

510, Chemical Engineering Design I
511, Chemical Engineering Design II
861, Transport Phenomena I
866, Transport Phenomena II
871, Advanced Process Design and Optimization
925, Selected Topics in Process Design and Optimization

CIVIL ENGINEERING

818, Adjustment of Surveys II
871, Urban Transportation Analysis I
872, Urban Transportation Analysis II
875, Traffic Engineering I
876, Traffic Engineering II

ELECTRICAL ENGINEERING

620, Analog Computation
665, Pulse Techniques
670, Servomechanisms
805, Advanced Feedback Control Systems
815, Information Theory
821, Noise Theory
831, Modulation Theory

MECHANICAL ENGINEERING

665, Engineering Analysis
731, Automatic Controls
732, Automatic Controls Labratory

RECENT AREAS OF RESEARCH

Heuristic control system simulator
Application of the maximum principle to industrial management and operations research
Optimization of reliability problems subject to linear and nonlinear restraints
Optimization of space system design
Scheduling school buses
A systems engineering approach to the design and optimization of environmental systems
Optimization of desalination systems
Human transmission of messages
Presentation and dissemination of training information
Communications of work methods
Manufacturing assembly instructions
Design of work stations
Controls for automotive brakes
The effect of social pressure on decision making
Design of controls using force as a criteria
The effect of background music on the control activity of an automobile driver
The physiological effect of a water cooled hood in a heat stress environment

ENROLLMENT AND GRADUATION STATISTICS

Enrollment

	Candidates at Present
M.S.	36
Ph.D.	4

Degrees Granted

	1960	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	*1967*
M.S.	1	3	5	7	12	20	11	19

Since the Ph.D. program in operations research was recently started at Kansas State University, there have been no graduates from this program.

University of Oklahoma

Norman, Oklahoma 73069

A full-time industrial engineering program was initiated here in 1963. Operations research was developed as a major part of the I. E. program.

Inquiries: Dr. Robert A. Shapiro, Chairman, Department of Industrial Engineering, University of Oklahoma, Norman, Oklahoma 73069.

DEGREES OFFERED

B.S. in Industrial Engineering
Master of Engineering (Industrial Engineering)
Ph.D. in Engineering (Industrial Engineering)

FACULTY

Primary Operations Research

B. L. Foote
J. W. Foster
R. A. Shapiro
H. A. Taha

Associated with Operations Research

R. A. Terry

COURSE OFFERINGS

Primary Operations Research

INDUSTRIAL ENGINEERING

235, Inventory Control
263, Introduction to Operations Research
302, Reliability
362, Mathematical Techniques of Operations Research
368, Applied Operations Research
402, Special Topics
461, Advanced Topics of Operations Research (Mathematical Programming)

225, Plant and Production Planning
336, Bionics

MATHEMATICS ELECTIVES

225, Linear Algebra
239, Game Theory
217, Numerical Analysis I
218, Numerical Analysis II
219, Mathematical Statistics I
220, Mathematical Statistics II
329, Theory of Probability
246, Advanced Calculus I
345, Advanced Calculus II
346, Advanced Calculus III
443, Calculus of Variations I
303, Topology
355, Complex Variables

ENGINEERING

144, Computer Programming
202, Computer Science
302, Advanced Computer Science

RECENT AREAS OF RESEARCH

Inventory Control
Queueing
Weapons Development

ENROLLMENT AND GRADUATION STATISTICS

Enrollment	*1967–68*
B.S. Candidates	56
M.S. Candidates	39
Ph.D. Candidates	23

Graduation Statistics	*1964*	*1965*	*1966*	*1967*
B.S. in Engineering	19	24	25	21
M.S. in Engineering	12	17	21	10
Ph.D.	1	0	0	2

Oregon State University

Corvallis, Oregon 97331

Approval for the offering of the M.S. in operations research was granted to the Department of Statistics in the spring of 1967. Prior to formal

recognition, this type of activity had been carried on for several years within the existing framework of the Department of Statistics.

The M.S. program in operations research is primarily intended for those students with interests in the mathematical methods pertaining to the field. There is not a Ph.D. program designated in operations research, but the flexibility inherent in the Ph.D. program in statistics makes it possible for some students primarily interested in operations research to continue beyond the M.S. level.

Inquiries: Dr. Lyle D. Calvin, Chairman, Department of Statistics, Oregon State University, Corvallis, Oregon 97331.

DEGREES OFFERED

M.S. in Operations Research
M.S. in Statistics
Ph.D. in Statistics

FACULTY

Primary Operations Research

G. D. Faulkenberry
D. Guthrie, Jr.
D. A. Pierce
D. R. Thomas

Associated with Operations Research

L. D. Calvin
E. J. Hughes
E. L. Kaplan
W. S. Overton
R. G. Petersen
F. L. Ramsey
J. L. Riggs
K. E. Rowe
H. L. Scheurman
T. L. Yates

COURSE OFFERINGS

Primary Operations Research

Stat. 371–373, Basic Statistics and Operations Research
Stat. 481–483, Theory of Statistics
Stat. 464–466, Theory of Probability
Stat. 456–457, Statistics for Engineering and Physical Science
Stat. 414–415, Data Systems Analysis
Stat. 417, Computer Simulation
Stat. 474, Inventory Analysis
Stat. 475, Queues
Stat. 476, Reliability Models
Stat. 571–573, Operations Research
Stat. 561–563, Applications of Stochastic Processes
Stat. 574–575, Advanced Topics in Mathematical Programming

Stat. 577–578, Decision Theory
Stat. 551–552, General Linear Hypotheses
Stat. 553, Multivariate Analysis
Stat. 591, Time Series Analysis

Associated with Operations Research

Stat. 426, Regression Analysis
Stat. 442, Sampling Theory
Stat. 432, Design of Industrial Experiments
I. E. 571–573, Systems Theory and Cybernetics
E. E. 590–592, Systems Simulation
E. E. 593, Simulation Fundamentals

RECENT AREAS OF RESEARCH

Production programming
Theory of games
Dynamic programming
Simulation of logistics systems
Mathematical inventory theory
Environmental systems
Decision theory

University of Houston

Houston, Texas 77004

Formal course work in operations research at the University of Houston began in 1951 and became a formal group of sequence electives in 1963. Operations research was made a formal option in the M. S. program in 1962. The Ph.D. program is planned to begin in September, 1968.

Inquiries: Professor Scott T. Poage, Chairman, Industrial Engineering Department, University of Houston, Houston, Texas 77004.

DEGREES OFFERED

B.S. in Industrial Engineering (Operations Research Elective Sequence)
M.S. in Industrial Engineering (Operations Research Option)
M.S. (Operations Research Option)

FACULTY

Primary Operations Research

C. R. Cupit	C. E. Donaghey	S. T. Poage
G. S. Dawkins	B. Goldberg	B. T. Rhodes

Associated with Operations Research

INDUSTRIAL ENGINEERING

J. T. Elrod — A. N. Paul

COMPUTER SCIENCE

R. J. Henry — M. B. Smith — J. B. Wyatt

ENGINEERING

S. B. Childs — R. L. Motard — G. F. Paskusz
E. L. Michaels

ENVIRONMENTAL SCIENCES

H. N. Myrick

COURSE OFFERINGS

Primary Operations Research

* I. E. 262, Introduction to Linear Programming
* I. E. 333, Engineering Economy I
* I. E. 363, Engineering Statistics I
I.E. 464, Engineering Statistics II
* I.E. 471, Operations Research I
* I.E. 472, Operations Control
** I.E. 533, Operations Research II
I.E. 536, Reliability and Quality Control
I.E. 567, Advanced Computing Techniques
I.E. 610S, 620S, 630S, 640S, 650S, Research
I.E. 611, Graduate Seminar
I.E. 632, Engineering Economy: Project Planning
I.E. 662, Engineering Statistics: General Linear Hypothesis
I.E. 663, Engineering Statistics: Design of Experiments
I.E. 665, Engineering Economy II
I.E. 667, Advanced Computer Programming
I.E. 668, Advanced Statistics Seminar
I.E. 670, Operations Research: Simulation of Industrial Systems
I.E. 671, Operations Research: Optimization Methods
I.E. 672, Operations Research: Mathematical Programming
I.E. 673–674, Master's Thesis
I.E. 730, Selected Topics
I.E. 731, Operations Research: Stochastic Processes
I.E. 732, Advanced Operations Research Seminar

*Required in undergraduate industrial engineering curriculum.
**Required in undergraduate industrial engineering or elective sequence.

ENROLLMENT AND GRADUATE STATISTICS

Enrollment

	1960–61	*1961–62*	*1962–63*	*1963–64*	*1964–65*	*1965–66*
Undergraduate	71	89	109	106	84	82
Graduate	37	46	41	38	42	74
Degrees Granted						
B.S.	13	9	7	4	14	19
M.S.	4	0	6	5	3	10

Illinois Institute of Technology

Chicago, Illinois 60616

Educational programs in operations research at Illinois Institute of Technology are conducted by the Department of Industrial Engineering. All undergraduate students in the department are required to take a two-course introductory sequence in operations research, as well as courses in statistics and computer science. A substantial part of the required curriculum in the Master's program is in operations research, and many students major in this area through the selection of elective courses and thesis topics. Most of the doctoral candidates major in operations research.

Inquiries: Dr. Stanley M. Block, Professor and Chairman, Department of Industrial Engineering, Illinois Institute of Technology, Chicago, Illinois 60616.

DEGREES OFFERED

B.S. in Industrial Engineering
M.S. in Industrial Engineering
Ph.D. in Industrial Engineering

FACULTY

Primary Operations Research

A. F. Johnson W. R. Ryder S. B. Smith
R. C. Morris

Associated with Operations Research

S. M. Block M. Z. Hassan A. R. Yeslin

COURSE OFFERINGS

Primary Operations Research

I.E. 321, Statistics
I.E. 420, Engineering Statistics

I.E. 440, Computer Science
I.E. 456, Mathematics for Operations Research
I.E. 457, Introduction to Operations Research
I.E. 480, Project Planning and Control
I.E. 527, Statistical Decision Theory
I.E. 528, Strategy of Experimentation I
I.E. 529, Strategy of Experimentation II
I.E. 541, Management Information Systems
I.E. 544, Computer Simulation
I.E. 550, Linear Programming
I.E. 551, Nonlinear Programming
I.E. 552, Queueing Theory
I.E. 553, Inventory Theory
I.E. 554, Theory and Management of Operational Systems
I.E. 556, Topics in Operations Research
I.E. 557, Operations Research Seminar
I.E. 558, Dynamic Programming
I.E. 559, Probability and Stochastic Processes
I.E. 564, Industrial Forecasting
I.E. 565, Industrial Scheduling

Associated with Operations Research

I.E. 441, Quality Control
I.E. 508, Industrial Economics
I.E. 512, Design of Manufacturing Enterprises
I.E. 516, Organization and Management
I.E. 520, Advanced Quality Control
I.E. 530, Human Engineering
I.E. 538, Seminar in Human Engineering

Courses in the Departments of Business and Economics, Mathematics, City and Regional Planning, other Departments of Engineering and Science, and the Information Science Center.

RECENT AREAS OF RESEARCH

Location problems—centers and medians of networks
Optimality in regression designs
Applications of the calculus of variations to operations research and mechanics
A model for determining a low cost configuration of assembly lines
Scheduling of dynamic lot sizes
Distribution of empty freight cars to shippers
Multi-level continuous sampling plans
Criteria for assigning models to assembly lines

ENROLLMENT AND GRADUATION STATISTICS

Enrollment (Industrial Engineering)

	1st Semester 1967–68
Undergraduate	
Part-time	16
Full-time	32
Graduate	
Part-time	88
Full-time	52

Degrees Granted (Industrial Engineering)

	1961	1962	1963	1964	1965	1966	1967
B.S.	30	22	27	25	14	18	25
M.S.	4	5	4	19	16	12	38
Ph.D.	—	—	—	—	2	1	4

The George Washington University

Washington, D.C. 20006

Operations research at George Washington first began in 1952 when the late Dr. Glen D. Camp joined the faculty in the newly initiated program in engineering administration. At present, in addition to the degree of Master of Engineering Administration, the Department of Engineering Administration, School of Engineering and Applied Science, offers a Master of Science degree in operations research and a Doctor of Science program with a choice of majors and minors (see Degrees Offered section).

Inquiries: Dr. H. E. Smith, Chairman, Department of Engineering Administration, School of Engineering and Applied Science, The George Washington University, Washington, D.C. 20006.

DEGREES OFFERED

M.E.A. in Engineering Administration
M.S. in Operations Research
D.Sc. in Engineering Administration
D.Sc. in Operations Research
D.Sc. in Systems Research (in cooperation with the Department of Electrical Engineering)

FACULTY

Primary Operations Research

FULL TIME

P. A. Crafton
D. Gross
J. L. Jenkins
J. Kaye
C. E. Pinkus

PART TIME

A. Blumstein J. E. Falk V. Selman

Associated with Operations Research

FULL TIME

R. E. Cronin P. S. Shane H. E. Smith
A. M. Rothrock J. B. Smith

COURSE OFFERINGS

Primary Operations Research

Operations Research I–II
Problems in Operations Research
Mathematical Methods for Operations Research
Linear Programming
Theory of Games
Queuing Theory
Nonlinear and Dynamic Programming
Production Control
Inventory Control

Associated with Operations Research

SYSTEMS

Systems Analysis and Management I–II
Systems Engineering I–II
Automatic Control Systems I–II–III
Information Theory I–II

COMPUTER SCIENCE

Automatic Data Processing Systems
Digital Computers
Machine and Assembly Language Programming
Algorithmic Methods and High-Level Languages
Finite State Machines
Computing Systems
Finite Automata
Digital Computer Programming Systems
Design of Computer and High-Level Languages

STATISTICS

Statistics for Engineers
Mathematical Probability and Applications
Mathematical Statistics

Markov Processes
Advanced Mathematical Probability
Distribution Theory
Experimental Design
Topics in Statistical Inference
Multivariate Analysis
Statistical Decision Theory
Time Series Analysis
Econometrics I–II

ECONOMICS

Survey of Economics
Microeconomic Theory I–II
Macroeconomic Theory
Productivity Analyses
Mathematical Economics

MATHEMATICS

Mathematical Methods in Applied Science I–II
Graph Theory
Advanced Calculus I–II
Numerical Analysis
Calculus of Variations
Theories of Optimization

RECENT AREAS OF RESEARCH

Inventory theory
Branch and bound logistics models
Logistics and transportation models
Quantitative applications in medical rehabilitation
Quantitative applications in crime prevention
Incentive contracting
Metropolitan area governmental concepts
Quantitative analysis of certain university functions

ENROLLMENT AND GRADUATION STATISTICS

Enrollment

	1st Semester 1967–68
M.E.A.	382
M.S. (O.R.)	36
D.Sc. (E.A.)	10
D.Sc. (O.R.)	20

Total Degrees Granted

M.E.A.	1250
M.S. (O.R.)	program began 1967
D.Sc. (E.A.)	1
D.Sc. (O.R.)	1

University of Pittsburgh

Pittsburgh, Pennsylvania 15213

Programs in the Department of Industrial Engineering, Systems Management Engineering, and Operations Research are structured to educate students with a foundation in the basic sciences, engineering and computers, plus a strong capability for systems design, analysis, and management, crossing disciplinary lines. The Ph.D. program, which was initiated in 1965, is called Systems Management Engineering and Operations Research.

In the doctoral curriculum, cognate area programs have been developed in conjunction with biostatistics, business, chemical engineering, computer science, electrical engineering, knowledge available systems, mathematics, mechanical engineering, and public and international affairs. The Ph.D. student is required to do graduate level work in two of these areas.

The operations research tenor of the doctoral program is existent in both the Bachelor of Science and Master of Science degrees in industrial engineering.

Inquiries: Dr. A. G. Holzman, Professor and Chairman, Department of Industrial Engineering, Systems Management Engineering and Operations Research, 508 Engineering Hall, University of Pittsburgh, Pittsburgh, Pennsylvania 15213.

DEGREES OFFERED

B.S. in Engineering (Industrial)
M.S. in Industrial Engineering
Ph.D. in Systems Management Engineering and Operations Research

FACULTY

Primary Operations Research

R. Curran	A. G. Holzman	Y. R. Wang
W. A. Greaney	I. B. Turksen	H. Wolfe

Associated with Operations Research

J. Belzer	L. Katz*	M. Mazumdar
A. Chapanis*	K. Kussmaul	H. W. Wolfarth
H. Ginsburg		

* Visiting Professor.

COURSE OFFERINGS

Primary Operations Research

I.E. 122, Numerical Analysis and Computers
I.E. 180, Mathematical Programming Fundamentals
I.E. 182, Operations Research
I.E. 222, Mathematical Model Design for Large Scale Systems
I.E. 243, Decision and Value Theory
I.E. 250, Digital Systems Simulation
I.E. 275, Systems Reliability and Maintainability Engineering
I.E. 283, Nonlinear Programming and Game Theory
I.E. 284, Stochastic Processes
I.E. 285, Geometric Programming
I.E. 286, Dynamic Systems
I.E. 287, Network Theory
I.E. 288, Scheduling Theory
I.E. 294, Advanced Stochastic Processes and Queuing Theory
I.E. 298, Research Projects in Systems

Associated with Operations Research

I.E. 171, Engineering Statistics I
I.E. 172, Engineering Statistics II
I.E. 173, Regression Analysis
I.E. 225, Systems Management I
I.E. 226, Systems Management II
I.E. 230, Man-Machine Engineering
I.E. 240, Advanced Engineering Economics Analysis
I.E. 261, Information Engineering II
I.E. 262, Information Engineering III
I.E. 264, Turing Machine Studies
I.E. 265, Problems in Automata Theory
I.E. 266, Context Free Languages
I.E. 268, Advanced Topics in Information Retrieval
I.E. 272, Analysis of Variance
I.E. 273, Experimental Design
I.E. 274, Regression Analysis

RECENT AREAS OF RESEARCH

Design of space information center for industrial development
Relevancy research
Computer based learning project
General purpose material handling simulator
An immediate feedback admissions system for General Hospital

Factors affecting quality of nursing care
Network analysis and the evaluation of airline operating costs
An analysis of the student information flow at the University of Pittsburgh
An investigation of the significance of the three time estimates used by PERT
An information system for an ungraded learning program
Computer generation of visual displays for a corporate financial review—a management information display system
Flexible data collection and report preparation using a real time computer
Time-sharing simulator of queues: a teaching aid
An evaluation of a method for improving search strategies in a coordinate searching system
Scheduling patients in an outpatient facility—a simulation approach
The application of linear programming to land planning
A probabilistic multiple shortage inventory model for hospital pharmacies
A computerized educational scheduling system
A comparison of keywork-in-context (KWIC) indexing to manual indexing
A mathematical decision making approach to the control of international conflict
Statistical methodology for increasing the efficiency, the occupancy rate, and predicting the bed requirements of the obstetrical unit
An interval definition of certainty in the min-max inventory model
Evaluating navigator proficiency by duplication simulation
A Markovian analysis of pupil progress through a system of individualized instruction

ENROLLMENT AND GRADUATION STATISTICS

Graduate Enrollment

	1963–64	*1964–65*	*1965–66*	*1966–67*	*1967–68*
M.S. (Industrial Engineering)	21	25	29	47	54
Ph.D. (Systems Management Engineering and Operations Research)	—	—	7	17	22

Degrees Granted

	1963–64	*1964–65*	*1965–66*	*1966–67*	*1967–68*
M.S.	12	10	15	8	16
Ph.D.	—	—	—	1	2

University of Massachusetts

Amherst, Massachusetts 01002

In 1966, the Department of Industrial Engineering established programs leading to an M.S. and a Ph.D. in industrial engineering with emphasis on operations research. The Ph.D. program is interdisciplinary in nature and can involve work in such areas as mathematics, business administration, engineering, and economics. Future plans of the Industrial Engineering Department call for a continuing expansion of the operations research program.

Inquiries: Dr. Richard W. Trueswell, Head, Department of Industrial Engineering, University of Massachusetts, Amherst, Massachusetts 01002.

DEGREES OFFERED

M.S. in Industrial Engineering (Operations Research Major)
Ph.D. in Industrial Engineering (Operations Research Major)

FACULTY

Primary Operations Research

INDUSTRIAL ENGINEERING

R. J. Giglio — R. F. Rikkers — R. A. Rubel
F. C. Kaminsky

Associated with Operations Research

BUSINESS ADMINISTRATION

M. W. Belovica — P. L. Cheng — U. Kaczka
G. Chen — A. W. Corceran

CHEMICAL ENGINEERING

R. J. Novak

COMPUTER SCIENCE

J. A. N. Lee — F. D. Stockton

ECONOMICS

J. K. Kindahl — R. S. Martin — R. J. Olsen

ELECTRICAL ENGINEERING

C. E. Hutchinson — R. V. Monopoli

INDUSTRIAL ENGINEERING

C. G. Drury — E. J. Rising — R. W. Trueswell

MECHANICAL ENGINEERING

W. A. Nash

COURSE OFFERINGS

In the following lists, courses bearing five and six hundred numbers are intended for both undergraduate and graduate students. Higher numbers are exclusively for graduate students.

Primary Operations Research

INDUSTRIAL ENGINEERING

I.E. 571, Basic Probability for Engineers
I.E. 752, Principles of Engineering Statistics
I.E. 578, Production Planning and Control
I.E. 579, Industrial Engineering Problems (Introduction to Operations Research)
I.E. 762, Computer Methods for OR/MS Applications
I.E. 779, Quantitative Methods in Industrial Engineering
I.E. 781, Advanced Topics in Operations Research I
I.E. 782, Advanced Topics in Operations Research II
I.E. 783, Simulation and Monte Carlo Techniques
I.E. 784, Stochastic Processes in Industrial Engineering
I.E. 791, Seminar in Operations Research

BUSINESS ADMINISTRATION

B.A. 756, Quantitative Methods in Business Administration
B.A. 757, Quantitative Methods in Business Administration
B.A. 804, Decision Models in Business Administration
B.A. 805, Research Methods in Business Administration
B.A. 806, Seminar in Quantitative Management Science
B.A. 821, Advanced Topics in Management Science I
B.A. 822, Advanced Topics in Management Science II

MATHEMATICS

Math. 557, Linear Programming and Theory of Games

Associated with Operations Research

INDUSTRIAL ENGINEERING

I.E. 700, Special Problems in Industrial Engineering
I.E. 754, Advanced Topics in Engineering Economy
I.E. 755, Quality Control and Reliability Engineering
I.E. 761, Data Processing Systems Analysis and Design

BUSINESS ADMINISTRATION

B.S. 550, Administrative Statistics
B.S. 841, Management Information Theory
B.S. 842, Management Control Systems
B.S. 851, Theory and Science in Marketing

COMPUTER SCIENCE

C.S. 409, Tools of Research Computer Language
C.S. 531, Introduction to Data Processing
C.S. 551, Calculus of Finite Differences
C.S. 552, Topics in Numerical Methods
C.S. 570, Boolean Algebra and Switching Theory
C.S. 787, Information Storage and Retrieval

ECONOMICS

Econ. 601, Decision Theory in Economics
Econ. 701, Microeconomic Theory
Econ. 702, Microeconomic Theory
Econ. 751, Mathematical Economics and Economic Model-Building
Econ. 752, Econometrics

ELECTRICAL ENGINEERING

E.E. 590, Feedback Control Systems I
E.E. 601, Random Signal Theory
E.E. 733, Digital Control Systems
E.E. 734, Optimum Control Systems
E.E. 746, Statistical Communication Theory

MATHEMATICS

Math. 533, Probability
Math. 551, Numerical Analysis I
Math. 552, Numerical Analysis II
Math. 611, Linear Algebra
Math. 625, Introductory Modern Analysis I
Math. 721, Theory of Functions of a Complex Variable
Math. 722, Theory of Functions of a Complex Variable
Math. 723, Theory of Functions of a Real Variable
Math. 724, Theory of Functions of a Real Variable
Math. 831, Advanced Ordinary or Partial Differential Equations
Math. 832, Advanced Ordinary or Partial Differential Equations

PSYCHOLOGY

Psy. 545, Psychological Statistics
Psy. 729, Quantitative Theories of Behavior
Psy. 744, Factor Analysis
Psy. 745, Advanced Applied Statistics
Psy. 746, Quantitive Methods in Psychology

STATISTICS

Stat. 561, Design of Experiments (Methods & Theory)
Stat. 562, Design of Experiments (Methods & Theory)
Stat. 572, Sampling Theory and Methods
Stat. 581, Multivariate Analysis (Methods & Theory)
Stat. 582, Multivariate Analysis (Methods & Theory)
Stat. 615, Introduction to the Theory of Statistics I
Stat. 616, Introduction to the Theory of Statistics II
Stat. 701, Statistical Test and Decision Procedures
Stat. 702, Statistical Test and Decision Procedures
Stat. 725, Estimation Theory and Hypothesis Testing
Stat. 726, Estimation Theory and Hypothesis Testing

RECENT AREAS OF RESEARCH

Hospital systems
Simulation of medical decisions
Capital budgeting and investment planning
Water resource management
Stochastic processes in production and inventory models
Information systems
Simulation techniques

ENROLLMENT AND GRADUATION STATISTICS

Enrollment

	1966	1967
M.S. (Operations Research Major)	0	4
Ph.D. (Operations Research Major)	1	4

The University of Wisconsin

Madison, Wisconsin 53715

Operations research is an interdisciplinary program at The University of Wisconsin, Madison. It is combined with administrative sciences into an Operations Research and Administrative Science Committee responsible to the Dean of the Graduate School. No formal undergraduate or gradu-

ate degrees are offered. An approved minor in ORAS for the Ph.D. is available. Graduate regulations permit the establishment of special advisory committees for an M.S. and Ph.D. degrees in areas not formally approved for these degrees. A graduate degree in operations research may be obtained in this way. The ORAS Committee has been in existence for three years. Operations research courses are taught in many departments, and coordination of courses is arranged through subcommittees on probability theory and statistical inference, optimization techniques, and administrative sciences. Undergraduate degrees are offered in several operations research related areas such as computer sciences, economics, industrial engineering, mathematics, and statistics.

Inquiries: Dr. Gerald Nadler, Chairman, Operations Research and Administrative Science Committee, The University of Wisconsin, 333 North Randall Avenue, Madison, Wisconsin 53706.

DEGREES OFFERED

B.S. (Degrees in Various Fields)
M.S.I.E. (Operations Research Major)
M.S. (Operations Research, by Special Arrangement)
Ph.D. (Industrial Engineering with Operations Research Major)
Ph.D. (Operations Research, by Special Arrangement)

FACULTY

Primary Operations Research

A. C. Connor
E. Davis
C. H. Falkner
J. Gurland
T. C. Hu
H. F. Karreman
R. F. Love
O. L. Mangasarian
W. A. Moy
P. Ney
A. Reisman
J. B. Rosen
D. L. Russell
D. R. Schuette
H. E. Thompson
G. C. Tiao
D. Uhlenbrock
Von Haehling

Associated with Operations Research

AGRICULTURAL ECONOMICS

D. L. Bawden

BUSINESS

A. C. Filley
E. Gaumnitz
A. Johnson
E. Weber

CHEMICAL ENGINEERING

C. A. Coberly
D. F. Rudd

ECONOMICS

E. R. Brubaker, J. M. Culbertson, D. J. Dodges, E. L. Feige, A. S. Goldberger, C. C. Holt, P. H. Lindert, D. A. Nichols, R. Perlman, H. W. Watts

ELECTRICAL ENGINEERING

T. J. Higgins, V. C. Rideout

INDUSTRIAL ENGINEERING

D. H. Gustafson, G. P. Huber, G. Nadler

MECHANICAL ENGINEERING

J. G. Bollinger, A. H. Seirig, S. M. Wu

POLITICAL SCIENCE

C. W. Anderson, H. C. Hart, H. Jacob, J. L. McCamy, C. C. Menges, C. Penniman, W. H. Young

SOCIOLOGY

B. C. Busching, A. F. Costonis, B. R. Fisher, C. B. Perrow, E. Rothstein, S. Spilerman

STATISTICS

A. P. Basu, G. Box, N. R. Draper, I. Guttman, J. Klotz, G. Roussas

COURSE OFFERINGS

Primary Operations Research

Operations Research Techniques I
Operations Research Techniques II
Operational Decisions in Production Management
Introduction to Theory of Probability
Control Systems Optimization and Synthesis
Applied Probability and Management Service
Operations Research
Theory and Applications of Linear Programming
Seminar in Operations Research
Operations Research Models in Industrial Engineering I
Operations Research Models in Industrial Engineering II
Advanced Statistical Experimental Design for Engineers
Production Planning and Control

Organization Theory and Practice
Linear Programming
Nonlinear Programming
Introduction to Optimization Methods
Statistical Quality Theory
Introduction to the Theory of Probability
Introduction to Bayesian Decision and Control I
Introduction to Bayesian Decision and Control II
Stochastic Models
Integer Programming and Network Flows
Dynamic Programming and Associated Topics

Associated with Operations Research

AGRICULTURAL ECONOMICS

Research in the Economics of Firm Management
Seminar in Quantitative Methods in Agricultural Economics Research

BUSINESS

Management and Employee Relations
Manpower Planning and Personnel Decisions
Administrative Behavior and Organizational Theory
Organization: Individual and Group Behavior
Applied Economics and Management Science

CHEMICAL ENGINEERING

Chemical Operations Analysis

COMPUTER SCIENCES

Algebraic Language Programming
Introduction to Numerical Analysis
Monte Carlo Methods
Matrix in Numerical Analysis
Complex Information Processing
Information Retrieval Theory and Techniques
Pattern Recognition and Adaptive Systems

ECONOMICS

Econometric Methods
Intermediate Income Theory
Macroeconomic Theory (Mathematical Section)
Topics in Economic Theory
Intermediate Price Theory
Measurement of Income and Capital
Applied Econometrics

INDUSTRIAL ENGINEERING

Manpower Utilization
Introduction to Industrial Operation
Theory of Design
Work Design and Measurement

POLITICAL SCIENCE

Seminar in Public Administration
Public Administration
Seminar: Comparative Public Administration
Introduction to Public Administration

SOCIOLOGY

Small Groups
Sociology of Complex Organizations
Industrial Sociology
Intermediate Social Psychology
Sociology of Occupations and Professions
Seminar: Complex Organization
Seminar: Industrial Sociology

STATISTICS

Introduction to Mathematical Statistics
Mathematical Statistics
Multivariate Analysis
Analysis of Variance and Experimental Designs I
Analysis of Variance and Experimental Designs II
Nonparametric Statistics
Statistical Theory of Dynamic Systems
Mathematical Models and Response Surface Methodology
Advanced Statistical Experimental Design for Engineers
Theory of Life Testing and Reliability
Reliability
Experimental Design

URBAN AND REGIONAL PLANNING

Land Use and Communications Systems Planning

Washington University

St. Louis, Missouri 63130

Courses in operations research are offered by the Department of Applied Mathematics and Computer Science in the School of Engineering and

Applied Science. This department has been in existence since 1964. Its predecessor organization was the Engineering Analysis and Operations Research Area, now disbanded. The department offers an undergraduate program in applied mathematics and graduate programs in applied mathematics, computer science, and operations research.

Inquiries: Professor Leon Cooper, Chairman, Department of Applied Mathematics and Computer Science, Washington University, St. Louis, Missouri 63130.

DEGREES OFFERED

B.S. in Applied Mathematics
M.S. in Applied Mathematics and Computer Science
D.Sc. in Applied Mathematics and Computer Science

FACULTY

Primary Operations Research

P. Brumbaugh
D. E. Burlingame
L. Cooper
D. W. Matula
D. I. Steinberg
A. C. Wheeler
G. S. Whitlow, Jr.
P. B. Zwart

Associated with Operations Research

APPLIED MATHEMATICS

W. E. Ball
J. D. Isaacson
I. N. Katz
E. Y. Rodin
R. Wette

COMPUTER SCIENCE

Y. H. Chuang
W. A. Clark
R. A. Cook
R. A. Dammkoehler
T. L. Gallagher
S. Pollack
T. D. Sterling

COURSE OFFERINGS

Primary Operations Research

UNDERGRADUATE

Eng. 353, Operations Analysis I
Eng. 453, Operations Analysis II

GRADUATE

Eng. 505, Special Topics in Mathematical Programming
Eng. 506, Discrete Dynamic Programming
Eng. 507, Special Topics in Optimization I
Eng. 508, Special Topics in Optimization II
Eng. 509, Linear Programming I

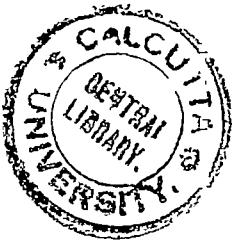
Eng. 510, Linear Programming II
Eng. 513, Reliability Theory
Eng. 515, Queuing Theory and Applications
Eng. 519, Simulation of Random Processes
Eng. 520, Design of Simulation Experiments
Eng. 523, Nonlinear Programming I
Eng. 524, Nonlinear Programming II
Eng. 528, Inventory and Production Control Theory
Eng. 531, Theory of Games

Associated with Operations Research

APPLIED MATHEMATICS AND COMPUTER SCIENCE

Eng. 132, Digital Computer Programming
Eng. 211, Applied Differential Equations
Eng. 261, Introduction to Computer Languages
Eng. 262, Automatic Languages for the Humanities
Eng. 307, Introduction to Statistical Data Processing
Eng. 308, Logic and Algorithms
Eng. 309, Matrix Algebra
Eng. 316, Applied Advanced Calculus I
Eng. 325, Engineering Statistics
Eng. 407, Applied Advanced Calculus II
Eng. 408, Combinatorial Mathematics
Eng. 409, Linear Algebra
Eng. 425, Numerical Data Processing and Experimental Design
Eng. 443, Methods of Applied Mathematics I
Eng. 444, Methods of Applied Mathematics II
Eng. 451, Computer Systems and Programming I
Eng. 452, Computer Systems and Programming II
Eng. 465, Numerical Methods
Eng. 500, Probability Theory
Eng. 501, Computer Programming Theory I
Eng. 502, Computer Programming Theory II
Eng. 503, Numerical Analysis I
Eng. 504, Numerical Analysis II
Eng. 511, Functional Analysis I
Eng. 512, Functional Analysis II
Eng. 514, Industrial Sampling Inspection and Reliability Testing
Eng. 516, Information Processing, Storage, and Retrieval
Eng. 517, General Systems Theory I
Eng. 518, General Systems Theory II
Eng. 521, Advanced Numerical Analysis I
Eng. 522, Advanced Numerical Analysis II

Eng. 525, Statistical Inference I
Eng. 526, Statistical Inference II
Eng. 527, Introduction to Automata Theory
Eng. 530, Finite State Machines
Eng. 532, Stochastic Processes
Eng. 533, Graphs and Networks
Eng. 534, Multiprogramming Systems
Eng. 535, Theory of Differential Equations I
Eng. 536, Theory of Differential Equations II
Eng. 537, Theory of Partial Differential Equations I
Eng. 538, Theory of Partial Differential Equations II
Eng. 539, Advanced Topics in Stochastic Processes



ELECTRICAL ENGINEERING

Eng. 421, Principles of Communication Theory
Eng. 460, Electronic Computer Design
Eng. 674, Digital Computer Circuits
Eng. 677, Communication Theory I
Eng. 678, Communication Theory II
Eng. 680, Advanced Topics in Digital Computers
Eng. 681, Computer Systems I
Eng. 682, Computer Systems II
Eng. 683, Principles of Artificial Intelligence
Eng. 685, Switching Circuits
Eng. 687, Digital Computers
Eng. 689, Theory of Hybrid Computation
Eng. 765, Introduction to Information Theory
Eng. 766, Advanced Topics in Information Theory

SYSTEMS AND AUTOMATIC CONTROL

Eng. 427, Automatic Control Design
Eng. 431, Control Systems I
Eng. 432, Control Systems II
Eng. 445, Control Systems III
Eng. 576, Mathematical Modeling of Dynamic Systems
Eng. 577, Automatic Control Systems
Eng. 579, Reliability of Systems and Components I
Eng. 580, Reliability of Systems and Components II
Eng 581, Statistical Analysis for Systems I
Eng. 582, Statistical Analysis for Systems II
Eng. 584, Optimal Control
Eng. 586, Stochastic Systems

MATHEMATICS

Math. 411, Advanced Calculus I
Math. 412, Advanced Calculus II
Math. 416, Functions of a Complex Variable
Math. 419, Integral Transforms
Math. 429, Linear Algebra I
Math. 430, Linear Algebra II

ECONOMICS

Econ. 535, Mathematical Economics
Econ. 536, Econometrics

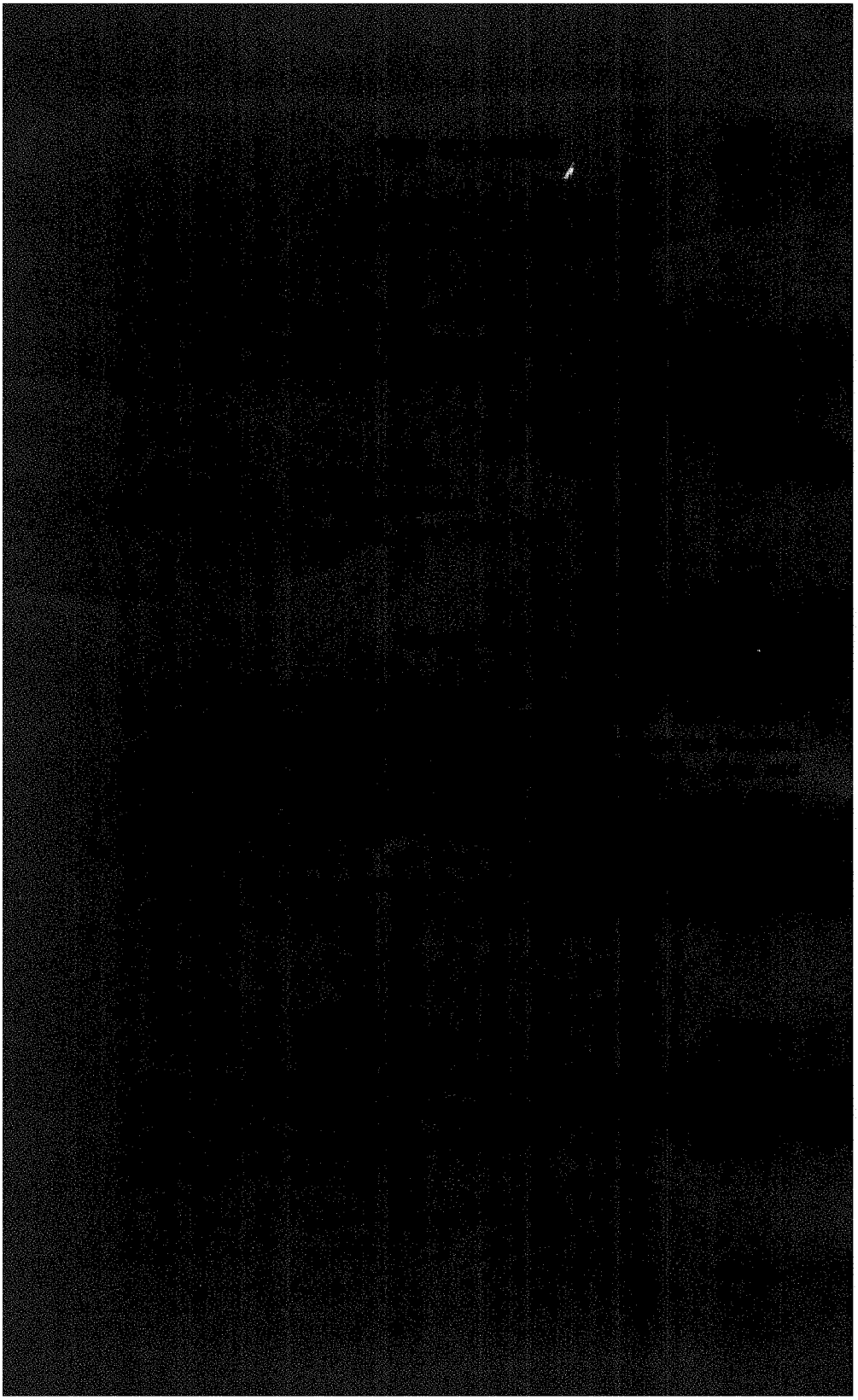
RECENT AREAS OF RESEARCH

Integer linear programming
Quadratic programming
Estimation of system reliability
Errors in regression models
Optimization in sequential search
Constrained global search
Fixed charge problems
Network planning techniques
Location-allocation problems
Inventory theory
Sequential sorting by dynamic programming

ENROLLMENT AND GRADUATE STATISTICS

Degrees Granted

	1964	1965	1966	1967
B.S.	2	4	6	8
M.S.	5	6	7	14
D.Sc.	0	1	4	4



Operations Research Society of America
1968-1969

OFFICERS OF THE SOCIETY

JOSEPH H. ENGEL, *President*
Communications Satellite Corp.
950 L'Enfant Plaza South, S.W.
Washington, D. C. 20024

THOMAS E. CAYWOOD, *Vice President*
Caywood-Schiller Associates
401 N. Michigan Avenue
Chicago, Illinois 60611

ROBERT E. MACHOL, *Secretary*
School of Business
Northwestern University
339 East Chicago Avenue
Chicago, Illinois 60611

KENNETH W. YARNOLD, *Treasurer*
System Development Corporation
2500 Colorado Avenue
Santa Monica, California 90406

COUNCIL OF THE SOCIETY

1966-69 *Past President*, GEORGE SHORTLEY, Booz, Allen Applied Research, Inc., 4733 Bethesda Avenue, Bethesda, Maryland 20014

1967-70 *Past President*, JOHN F. MAGEE, Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts 02140

1968-71 *Past President*, JOHN E. WALSH, Statistics Department, Southern Methodist University, Dallas, Texas 75222

1966-69 WALTER L. DEEMER
Arms Control and Disarmament Agency
New State Department Bldg.
Washington, D. C. 20451

GEORGE E. NICHOLSON, JR.
Department of Statistics
University of North Carolina
Chapel Hill, North Carolina 27515

1967-70 ERNEST KOENIGSBERG
Matson Research Corporation
215 Market Street
San Francisco, Calif. 94105

GEORGES BRIGHAM
Arthur Anderson & Company
69 West Washington Street
Chicago, Illinois 60602

1968-71 CHARLES D. FLAGLE
The Johns Hopkins University
School of Hygiene and Public Health
Baltimore, Maryland 21205

DAVID S. STOLLER
U.S. Office of Education
Washington, D. C. 20202

BUSINESS OFFICE

Requests for membership information and applications as well as subscriptions and orders for back issues of *Society* publications should be addressed to:

Operations Research Society of America
428 East Preston Street
Baltimore, Maryland 21202

EDITORS OF ORSA PUBLICATIONS

OPERATIONS RESEARCH
The Journal of the Operations Research Society of America
HUGH J. MISER, *Editor*
The Travelers Research Center
250 Constitution Plaza
Hartford, Connecticut 06103

TRANSPORTATION SCIENCE
ROBERT HERMAN, *Editor*
GM Research Laboratories
12 Mile and Mound Roads
Warren, Michigan 48090

BULLETIN of the Operations Research Society of America
GORDON CROOK, *Editor*
175 Adams Street
Brooklyn, New York 11201

INTERNATIONAL ABSTRACTS IN OPERATIONS RESEARCH
HUGH E. BRADLEY, *Editor*
The Upjohn Company
Kalamazoo, Michigan 49001

PUBLICATIONS IN OPERATIONS RESEARCH
DAVID B. HERTZ
McKinsey & Company, Inc.
245 Park Avenue
New York, New York 10017

COMMITTEES AND REPRESENTATIVES

*Membership Committee**
EZRA KRENDEL, *Chairman*
Management Science Center
University of Pennsylvania
Philadelphia, Pennsylvania 19104

*Education Committee**
JACK R. BORSTING, *Chairman*
Dept. of Operations Analysis
U.S. Naval Postgraduate School
Monterey, California 93940

*Publications Committee**
ROBERT OLIVER, *Chairman*
Operations Research Department
University of California
Berkeley, California 90024

*Nominating Committee**
ALFRED BLUMSTEIN, *Chairman*
Institute for Defense Analyses
400 Army-Navy Drive
Arlington, Virginia 22202

Lanchester Price Committee
GEORGE SHORTLEY, *Chairman*
Booz, Allen Applied Research, Inc.
4733 Bethesda Avenue
Bethesda, Maryland 20014

Sections Committee
WILLIAM NEMEREVER, *Chairman*
571 North 169th Street
Seattle, Washington 98133

Meetings Committee
ALLAN HARBAUGH, *Chairman*
LTV Electro Systems Inc.
Box 6118
Dallas, Texas 75222

* Standing Committees

Representative to IFORS
JOHN F. MAGEE
Arthur D. Little, Inc.
35 Acorn Park
Cambridge, Massachusetts 02140

Representative to the NRC
HUGH J. MISER
The Travelers Research Center
250 Constitution Plaza
Hartford, Connecticut 06103

Long Range Planning Committee
THOMAS E. OBERBECK, *Chairman*
Office of Research Analyses (RRRR)
Holloman AFB, New Mexico 88330

Representatives to the AAAS
W. EDWARD CUSHEN
National Bureau of Standards
U.S. Department of Commerce
Washington, D. C. 20234

ELLIS A. JOHNSON
4819 Essex Avenue
Chevy Chase, Maryland 20015

BERNARD B. WATSON (Alternate)
Research Analysis Corporation
McLean, Virginia 22101

Representative to the Conference Board on Mathematical Sciences
ALEX M. MOOD
Public Policy Research Organization
University of California
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Program of the Thirty-Fourth National Meeting

REGISTRATION INFORMATION....B-226
SUMMARY OF EVENTS....B-229
COMMITTEE FOR THE MEETING....B-231
SESSION CHAIRMEN....B-232
INDEX OF PARTICIPANTS....B-233
PROGRAM OF THE MEETING....B-236
ABSTRACTS OF THE PAPERS....B-258

Society Affairs

The ORSA Council Meeting....B-314

News and Announcements....B-319

THE PHILADELPHIA MEETING

REGISTRATION INFORMATION

Registration

The registration desk will be located on the 3rd floor of the Sheraton Hotel and will be open:

Tuesday, November 5	6:00 PM–10:00	PM
Wednesday, November 6	8:00 AM– 5:00	PM
Thursday, November 7	8:00 AM– 5:00	PM
Friday, November 8	8:00 AM–NOON	

Fees for registration and luncheons are as follows.

ORSA Member	$15.00
Non-member*	20.00
Full-time Student	3.00
Thursday Luncheon	4.50
Cocktail Party	3.00
Long Range Planning Luncheon	4.50

Except for a few designated guests and non-member invited speakers, all attendees are expected to register and pay fees. This includes speakers, panel members, and session chairmen.

Pre-registration

Pre-registration is encouraged. Pre-payment for the luncheons are advised due to space limitations. A form for pre-registration is enclosed. Please pay only by check or money order (do not send cash) payable to ORSA Meeting 1968 to the Registration Chairman: Bernard B. Rosenman, Frankford Arsenal, Philadelphia, Pa. 19137. Attention: ORSA Meeting (W5000).

Accomodations

The Sheraton Hotel has reserved 350 rooms for this meeting, with additional overflow capacity in nearby hotels. Daily rates for the Sheraton are listed on the

* A non-member wishing to apply for membership when registering may have $5 of this fee credited towards his annual dues payment of $12.50.

enclosed hotel reservation form. To reserve a room, mail the enclosed form directly to the Sheraton Hotel, not to the registration chairman.

Comments on Program

The annual meeting is returning to Philadelphia, the City of Brotherly Love, with a wide variety of OR applications in industry and government. The sessions cover the areas of OR in marketing, economics, finance, process industry, transportation, aerospace, military, social welfare, education and health. In addition, there is a tutorial paper on Speculations on the Year 2000 presented by Herman Kahn, a round table discussion luncheon, and films.

Tutorial
Speculations on The Year 2000
Sponsored By The Philadelphia Section of ORSA

Since 1961, Herman Kahn has been Director of the Hudson Institute, a nonprofit private research center studying the major problems affecting U.S. public policy. He was formerly a senior physicist at Rand. His previous books: *On Thermonuclear War; Thinking About the Unthinkable; on Escalation: Metaphors and Scenarios* have had considerable impact on the U.S. defense policy in the nuclear age.

Mr. Kahn will be discussing his recent research, summarized in the book *The Year 2000,* co-authored by Anthony J. Wiener. This work was done under the auspices of the Committee of the Year 2000 of the American Academy of Arts and Sciences. The objective was to explore a number of probable and possible alternate worlds or scenarios, based on extrapolations of basic economic and social time series. The study rejects the view that history is the sum of random occurrences. Instead, it holds that it is possible to plan ahead to achieve a life more than merely livable.

LADIES' PROGRAM

Wives of attendees are cordially invited to attend all sessions as guests of ORSA. Also, room 530 on the fifth floor of the Sheraton Hotel has been set aside as a hospitality suite for ladies attending the meeting. Coffee and sightseeing information will be available there daily.

The Sheraton Hotel is located at 1725 John F. Kennedy Boulevard, in the heart of the new Penn Center area. The Philadelphia Convention and Tourist Bureau is located at 1525 John F. Kennedy Boulevard, just one block from the Sheraton.

Philadelphia and its vicinity offer many attractions. The ladies' program committee, assisted by a Convention Bureau receptionist with expert knowledge of Philadelphia and its many attractions for visitors, will provide you with suggestions on what to see, where to go and what to do while you are in the city.

A walking tour of historic Philadelphia; a day-long bus tour of famed Bucks County historic landmarks, the New Hope Village art colony, and shopping tour of Peddler's Village specialty shops; tour of Longwood Gardens in Kennett Square, and visits to world-famous cultural institutions in Philadelphia are just a few of the many exciting places to visit while attending the ORSA National Meeting.

CLIMATE AND DRESS IN PHILADELPHIA FOR NOVEMBER

In the first two weeks of November the average daily temperature is 48°, with average high of 60° and average low of 34°.

This, of course, is topcoat weather, and topcoats are also recommended for the ladies, although woolen suits usually can be worn during the day and early evening.

COPIES OF PAPERS

Requests for copies of papers, also for information about the papers, should be made directly to the authors. Their addresses are contained in the statement of their affiliation. Please do not contact any of the committee for the meeting, the session chairmen, or the Editor of The Bulletin about the papers that are presented. Also, panel members should be contacted directly about their discussions.

LENGTH OF PAPERS

Invited papers are designated with an asterisk in this program. Ordinarily, invited papers are scheduled for 30 minutes, with an additional 10 minutes for discussion. Contributed papers are scheduled for 10 minutes with an additional 5 minutes for discussion. The program is rather tightly scheduled and all authors are urged to stay within their time allowance.

IDENTIFICATION OF SESSIONS AND PAPERS

Abbreviations are used to identify the technical sessions and papers in these sessions. The first letter denotes day of the week—W, T, of F. The second denotes AM or PM or evening and is A, P, or E. A number occurs next and identifies the type of session.

SUMMARY OF EVENTS

	Wednesday, November 6	AM	Room
WA1	Human Resources Development	9:00–11:30	Independence
WA2	Techniques	9:00–11:30	Connie Mack
WA3	Large Scale Business Systems Efficiency	9:00–11:30	Pennsylvania–East
WA4	Transportation Systems Efficiency	9:00–11:30	Delaware Valley Suite
WA5	Warfare and Reliability Systems	9:00–11:30	Room 540/546
WA6	Scheduling and Forecasting	9:00–11:30	Room 548/554

	Wednesday, November 6	PM	Room
WP	Mr. Herman Kahn: Tutorial Session I	12:30–1:50	Pennsylvania—West
WP1	Problems of Implementing Complex Industrial Systems	1:50–4:40	Independence
WP2	Adaptive Models in Marketing	1:50–4:40	Connie Mack
WP3	O.R. Applications to Space System Analysis	1:50–4:40	Pennyslvania—East
WP4	O.R. Theory—Military Applications	1:50–4:40	Constitution
WP5	Systems Approach to Community Problems	1:50–4:40	Room 548/554
WP6	Information Storage and Retrieval	1:50–4:40	Room 540/546
WP7	Integer Programming	1:50–4:40	Delaware Valley Suite
WP	Herman Kahn: Tutorial Session II	4:40–6:00	Pennsylvania—West

	Thursday, November 7	AM	Room
TA	Herman Kahn: Tutorial Session III	8:00–9:00	Pennsylvania—West
TA1	Planning and Control of R&D—Part I	9:20–12:00	Independence
TA2	Mathematical Analysis of Perception and Preference	9:20–12:00	Connie Mack
TA3	Models of the Firm	9:20–12:00	Room 540/546
TA4	O.R. Methodologies and Technologies for Space Sciences	9:20–12:00	Pennsylvania—East
TA5	The Diverse Views of the Role of C/E Analysis in Weapons and Force Selection	9:20–12:00	Constitution
TA6	Human Resources	9:20–12:00	Room 548/554
TA7	Management Informations Systems	9:20–12:00	Delaware Valley Suite

	ORSA Special Business Meeting	1:45–2:30	Pennsylvania—West
	Thursday, November 7	**PM**	**Room**
TP1	Planning & Control of R&D—Part 2	2:30–5:15	Independence
TP2	O. R. in Finance	2:30–5:15	Room 540/546
TP3	O. R. in the Pharmaceutical Industry	2:30–5:15	Connie Mack
TP4	O. R. in Engineering Design	2:30–5:15	Room 556/558
TP5	Workshop on O. R. Applications in Space Operations Management	2:30–5:15	Pennsylvania—East
TP6	Cost-Effectiveness in Health	2:00–5:15	Room 548/554
TP7	Workshop in Simulation	2:00–5:15	Delaware Valley Suite
	Space Science Business Meeting	5:15–5:45	Pennsylvania—East
	Friday, November 8	**AM**	**Room**
FA1	O. R. in the Chemical Industry	9:00–11:45	Connie Mack
FA2	Transportation Section—Invited Papers	9:00–11:45	Room 556/558
FA3	Vietnam Applications	9:00–11:45	Delaware Valley Suite
FA4	Opportunity in Education Cost Effectiveness Section	9:00–11:45	Room 540/546
FA5	New Techniques and Applications of O.R.	9:00–11:45	Room 548/554
FA6	Contributed Papers—Aerospace Systems	9:00–11:45	Independence
FA7	Contributed Papers	9:00–11:45	Pennsylvania—East
	Friday, November 8	**PM**	**Room**
FP1	O. R. in Insurance	1:30–4:00	Room 548/554
FP2	O. R. in the Petroleum Industry	1:30–4:00	Connie Mack
FP3	Cost-Benefits in Transportation	1:30–4:00	Room 556/558
FP4	O. R. in the Aerospace Industry	1:30–4:00	Pennsylvania—East
FP5	O. R. in Education	1:30–4:00	Room 540/546
FP6	Contributed Papers—Production and Distribution Management	1:30–4:00	Independence
FP7	Contributed Papers—The Traveling Salesman Problem	1:30–4:00	Delaware Valley Suite

COMMITTEE FOR THE PHILADELPHIA MEETING

Meeting Chairman:	LEO ROGIN *U.S. Naval Air Development Center* *Johnsville, Pa.*
Program Chairman:	SIDNEY HESS *Dept. of Statistics and Op. Res.* *Wharton School, Univ. of Pa.* *Philadelphia, Pa. 19104*
Publicity:	LAWRENCE FEIDELMAN *AUERBACH Corporation* *121 North Broad Street* *Philadelphia, Pa. 19107*
Registration:	BERNARD B. ROSENMAN *Frankford Arsenal* *Philadelphia, Pa. 19137*
Special Events:	JOHN KETTELLE *Kettelle Associates, Inc.* *Paoli, Pa. 19301*
Meeting Advisor:	LE ROY BROTHERS *Dean of Engineering* *Drexel Institute of Technology* *Philadelphia, Pa. 19104*
Arrangements:	LOUIS P. CLARK *General Electric VFSTC, Rm. 2432U* *P. O. Box 8555* *Philadelphia, Pa. 19101*
Contributed Papers:	STEPHEN W. LEIBHOLZ *Analytics, Inc.* *Camden, N. J.*
Finance:	ROBERT STARK *University of Delaware* *Newark, Delaware 19711*
Ex-Officio:	IRWIN GROSS *Wharton School* *University of Pa.* *Philadelphia, Pa. 19104*
Ex-Officio:	DJOERD HOEKSTRA *Pennsalt Chemical Co.* *Philadelphia, Pa.*

SESSION CHAIRMEN

WP1	L. G. Locke
WP2	Patrick J. Robinson
WP3	Joe Ravenis
WP4	Walter Deemer
WP5	Boyd Z. Palmer
WP6	Mary Hawes
WP7	Egan Balas
TA1	Lawrence S. Hill
TA2	Patrick J. Robinson
TA3	William Brinkloe
TA4	Glenn D. Self
TA5	Martin D. Schwartz
TA6	Athelston Spilhaus
TA7	Alan Hoffman
TP1	Lawrence S. Hill
TP2	James L. Bicksler
TP3	Michael Leyzorek
TP4	R. M. Stark
TP5	M. W. Lodato
TP6	Robert Grosse
TP7	Steve Leibholz
FA1	Stacy Rowley
FA2	Donald Capelle
FA3	Richard Swersey
FA4	Roger Sisson
FA5	S. Matlin
FP1	Gordon Shellard
FP2	Robert A. Franzoni
FP3	William H. Skaggs
FP4	Harold C. Sebring
FP5	David S. Stoller

INDEX OF PARTICIPANTS

Ackoff, Russell L.: TP4.0
Albert, Bernard S.: TA6.2
Ames, Marvin: FP2.1
Ancker, Jr., Clinton P.: FPL
Anderson, Loren E.: FP6.1
Anderson, Richard L.: WA1.1
Archer, Stephen H.: TA2.1
Arms, Ronald L.: WP4.4
Asher, Donald T.: TP3.3
Ashour, Said: WA6.2
Augusta, Joseph: WA5.7

Baker, Norman R.: WA3.6
Balas, Egan: WP7.0, WP7.3
Barash, Moshe M.: FP6.3
Barnes, Frank C.: FA2.4
Bartlett, III, Dwight K.: FP1.5
Bassin, W. M.: WA6.7
Behrns, Vernon N.: WA5.1
Bellmore, M.: FP7.2
Bench, Nachman: WP5.2
Bennett, Peter D.: TP2.2
Berra, P. Bruce: FP6.3
Berstein, Gilbert: TP6.3
Bicksler, James L.: TP2.0, TP2.3
Blumstein, Alfred: FA5.1
Bobis, Arthur H.: TA1.2
Bodin, L. D.: WA1.5
Bolland, Thomas W.: WA4.5
Boodman, David M.: FP1.2
Boose, J. A.: FP4.2
Bowden, George E.: FA6.3
Bradley, Hugh E.: TP3.2
Bragg, John M.: FP1.1
Brinkloe, William: TA3.0
Brocken, Jerome: WP4.4
Brown, Billy: TA6.1
Brown, David B.: WA5.6
Brown, Oliver S.: FA4.3
Buchwald, Rudolph W.: FP2.3
Busch, G. A.: FP3.1

Burton, Ellison S.: WA1.1, TP6.2
Buzby, Bruce R.: WP1.4

Capelle, Donald: FA2.0
Carroll, J. Douglas: TA2.3
Case, Leland S.: WA4.6
Charnes, A.: TA3.1
Childs, Martin L.: WA3.5
Cook, Victor J.: WP2.4
Cooper, W. W.: TA3.1
Cushen, W. Edward: WP5.1

Daellenbach, Hans: TP2.1
Dalkey, N.: FA5.2
Dean, Burton V.: FA5.3
De Cani, John: TP7.0
Deemer, Walter L.: WP4.0
Doering, Robert D.: TP1.2
Driscoll, Leo C.: TP5.0
Drowns, Robert E.: FA6.4
Duke, Richard: WP5.3
Dunn, B. J.: WA5.2

Easley, Ronald L.: TA5.0
Enlow, Ronald A.: TP1.3
Etter, Jr., Daniel O.: WA2.3
Evans, Leonard: FA2.1

Feidelman, Lawrence A.: FP4.4
Ferguson, Allen: FP3.2
Ferguson, Aubin O.: TA4.5
Finkler, Gene A.: WA6.5
FitzRoy, Peter T.: WP2.2
Franzoni, Robert A.: FP2.0

Getz, Charles J.: TA6.4
Glasserman, Jose: FA4.1
Glover, Fred: WP7.4
Goldman, A. J.: WA2.4, WA4.1
Gomory, Ralph E.: WP7.2
Grant, Robert B.: FA1.4
Gravers, Glen: WP7.1

GRAY, PAUL L.: **FA3.2**
GREEN, MURRAY: **TA7.1**
GREEN, PAUL E.: **TA2.1**
GREENE, TERRELL E.: **WP4.3**
GRISWOLD, GRAFTON: **WA5.5**
GROSSE, ROBERT N.: **TP6.0**
GUHA, D. K., **FP7.3**
GUTENBERG, ARTHUR W.: **TP1.4**

HAASE, RICHARD H.: **FA2.5**
HALPERN, IRWIN P.: **TA3.3**
HARLAN, CHARLES: **TP5.0**
HAWES, MARY: **WP6.0**
HAZELWOOD, R. NICHOLS: **TA5.0**
HELLY, WALTER: **TA6.3**
HENRY, JOHN J.: **TA3.4**
HERNITER, JEROME D.: **WP2.4**
HERTZ, DAVID B.: **FA5.4**
HILL, LAWRENCE S.: **TA1.0, TP1.0**
HOFFMAN, ALAN: **TA7.0**
HOFFMAN, FRED S.: **FPL**
HOLDSWORTH, JOHN R.: **WA2.1**
HOWARD, NIGEL: **FA3.1**
HOWSE, J. L.: **TA4.3**
HUGHES, E. C.: **TA1.1**
HULBERT, FROMAN: **WA6.1**

JELMERT, ANDREW: **WA1.2**
JENNER, RICHARD: **WA5.7**
JEWELL, WILLIAM S.: **TP4.0**

KAHN, HERMAN: **WP, WP, TA**
KAHN, PAUL M.: **FP1.3**
KARMARKOV, V. H.: **WA3.4**
KELLY, EAMON M.: **TP2.2**
KELLY, J. P.: **FP6.1**
KRUNNERT, HERMAN C.: **WP7.1**

LAURENT, ANDRE G.: **WA5.4**
LAVE, LESTER B.: **WA4.6**
LAWLER, E.: **FA5.5**
LAZARUS, STEPHEN S.: **FP6.2**
LEE, E. STANLEY: **WA6.3**
LEIBHOLZ, STEPHEN: **TP7.0**
LEIMKUHLER, FERDINAND F.: **FA6.5**
LEVIN, HENRY M.: **FA4.2**
LEYZOREK, MICHAEL: **TP3.0**
LIFSEY, JEREMY: **TA6.1**
LINDSAY, GLENN F.: **WP4.2**
LITTLE, JOHN D. C.: **WP2.1**
LOANE, EDWARD P.: **WA2.5**
LOCKE, LAURANCE G.: **WP1.0**
LODATO, MICHAEL W.: **TP5.0**
LUSTICK, L. S.: **WA2.1**

MALONE, J. C.: **FP7.2**
MARTZ, JR., HARRY F.: **WA5.6**
MATLIN, SAMUEL: **FA5.0**
MAYER, JR., ROBERT H.: **WA3.2**
MCCARTHY, JR., J. F.: **TA1.3**
MCGUIGAN, JAMES: **TP2.3**
MCMASTERS, ALAN W.: **FA3.3**
MELANDER, E. R.: **TP2.2**
MEYERS, P. R.: **WA2.4**
MILILLO, FRANK: **TP7.0**
MILLER, DAVID A.: **TA6.1**
MILLIE, HAROLD: **WP5.1**
MINTY, WILLIAM R.: **FA6.3**
MOOR, CHARLES L.: **FA3.5**
MOORE, J. M.: **FA5.5**
MOORE, ROBERT C.: **FA6.3**
MOREY, RICHARD S.: **FA3.4**
MORRIS, HENRY J.: **FA1.1**
MORTON, ANTON S.: **FP5.2**
MUNJAL, P.: **FA2.3, FP2.2**
MUSTIN, THOMAS M.: **FA3.3**

NELSON, ROBERT A.: **FP3.3**

OBERBECK, THOMAS E.: **FPL**
OBERUC, RICHARD E.: **FP7.1**
O'BRIEN, RICHARD J.: **FP5.3**
OLIVER, EDWARD P.: **TA5.0**
ORGLER, YAIR E.: **WA3.3**
OSTROFSKY, BENJAMIN: **TP1.1**

PALMER, BOYD Z.: **WP5.0**
PARKS, GEORGE M.: **TPL**
PEGELS, C. CARL: **WA1.2**
PETRUCCI, JR., JOHN E.: **FP4.3**
PEUCE, T. E.: **TA4.3**
PING, ROBERT A.: **FA6.6, TP7.0**

PLOTKIN, IRVING H.: **FP1.2**
PRITSKER, ALAN B.: **TP1.3**
RADNOR, MICHAEL: **WP1.3**
RANDOLPH, P. H.: **WA5.2**
RAO, ARTHUR G.: **WA6.4**
RAVENIS, JOE: **WP3.0**
REISMAN, ARNOLD: **FP5.1**
RILAND, LANE: **WP1.2**
ROACH, JONES W.: **TP5.0**
ROBBINS, THEODORE D.: **WP1.1**
ROBINSON, PATRICK J.: **WP2.0, TA2.0, TA2.2**
ROEFS, T. G.: **WA1.5**
ROGIN, LEO: **FP4.4**
ROSENTHAL, MYRON R.: **WA4.3**
ROTHERY, RICHARD: **FA2.2**
ROTLAND, CUREY H.: **TA4.4**
ROWLEY, JR., STACY N.: **FA1.0**

SANDER, WILLIAM E : **TA1.4**
SANJOUR, WILLIAM: **WA1.1, TP6.2**
SASTRY, M. V. RAMA: **WA6.6**
SCHOTTA, JR., CHARLES: **TA6.4**
SCHOW, II, HORACE, **WA5.3**
SCHWARTZ, MARTIN D.: **TA5.0**
SEBRING, HAROLD C.: **FP4.0**
SELF, GLENN: **TA4.0, TA4.1**
SHAKT, LEONARD Y.: **FA6.1**
SHANK, KENNETH E.. **FP4.1**
SHAPIRO, ARTHUR: **WA6.4**
SHAPIRO, JEREMY F.: **WP7.6**
SHELLARD, GORDON D.: **FP1.0**
SHWIMER, JOEL: **WP2.1**
SISSON, ROGER: **FA4.0**
SKAGGS, ALLEN H.: **FP3.0**
SLOAN, ALFRED P.: **WP7.6**
SMITH, KEITH V.: **WA4.4**
SOMMERS, ALEXIS N.: **FA6.5**
SPICER, F. L.: **WP4.3**
SPILHAUS, ATHELSTON: **TA6.0**
SPRATT, THOMAS L.: **FP2.3**
SQUIRE, DANA D.: **TP3.1**
STARK, ROBERT M.: **WA3.2, TP4.0**
STEDRY, A.: **TA3.1**
STEVENKEL, ARTHUR: **FA1.3**
STOCKFISCH, JACOB A.: **TA5.0**
STOLLER, DAVID S.: **FP5.0**
STROM, R. L.: **TA1.3**
SWALM, RALPH O.: **FA1.5**
SWERSEY, RICHARD J.: **FA3.0**
SWINSON, G. E.: **WA5.2**

TAFT, MARTIN I.: **FP5.1**
TAPAN, ROY: **FP1.4**
TAYLOR, HOWARD L.: **FP2.3**
THOMAS, CLAYTON J.: **WP4.1**
THOMAS, GERALD L.: **WP7.5**
TIERNEY, DONALD: **WA3.1**
TREMBLAY, HAL: **TP7.0**

UNGAR, ANDREW: **FA6.2**
URBAN, GLEN: **WP2.3**

VAUGHAN, JAMES A.: **TA3.2**
VOGT, ROBERT L.: **WP4.2**
VOSS, ROBERT G.: **TA4.4**

WAGNER, DONALD: **TA4.2**
WAGNER, JR., FREDERICK A.: **FA2.4**
WAGNER, W. H. L.: **WA1.4**
WEISS, JEFFREY H.: **TP6.1**
WHIRSTON, ANDREW: **WP7.1**
WHITE, WILLIAM W.: **WA4.2**
WILDE, DOUGLAS J.: **FA5.6**
WILLIAMS, JAY: **FA3.5**
WINBIGLER, MILES: **WA3.1**
WIND, YORAM: **TA2.2**
WOLFE, HARVEY: **WA3.5**
WOOD, PAUL M.: **FP6.4**

YAHYA, Q. A. M. M.: **WA2.2**
YORMACK, JONATHAN S.: **WA3.6**
YOUNG, JOHN: **WP6.0**

ZAHRADNIK, R. L.: **FA1.2**
ZINTON, JUDITH: **FP5.3**

PROGRAM

of the

THIRTY-FOURTH NATIONAL MEETING

of the

OPERATIONS RESEARCH SOCIETY OF AMERICA

Film Show at ORSA Meeting
Tiered Balcony (100)

Films will be shown on Wednesday, Thursday and Friday at the following times:

Wednesday	Thursday	Friday
12:30 p.m.–6 p.m.	9 a.m.–12 noon	9 a.m.–11:45 a.m.
7:00 p.m.–9 p.m.	2 p.m.–5 p.m.	1:15 p.m.– 4 p.m.

The films are informative and deal with a variety of subjects such as computer simulation, progress in space technology, reliability engineering, way of life and problems faced by people in different countries and other miscellaneous subjects which may interest members attending the conference. It is expected that the show will provide an opportunity for a refreshing break during the conference.

WEDNESDAY AM, NOVEMBER 6 INDEPENDENCE ROOM

Session WA1: 9:00–11:30:AM

Human Resources Development

WA1.1 **Air Pollution Abatement Models,** ELLISON S. BURTON, WILLIAM SANJOUR and RICHARD L. ANDERSON, *Ernst and Ernst, Washington, D.C.*

WA1.2 **Absorbing Markov Chain Models Applied to Blood Bank Problems,** C. CARL PEGELS and ANDREW JELMERT, *Department of Management Science, State University of New York.*

WA1.3 **Group Formation and Persistence in Social Systems,** LOUIS G. VARGO, *Western New Mexico University.*

WA1.4 **An Application of Integer Programming for Legislative Redistricting,** W. H. WAGNER, *Management Services, Union Carbide Corporation and CROND, Incorporated, Delaware.*

WA1.5 **Nonlinear Programming Approach to the Optimization of a Generalized Reservoir System,** LAWRENCE D. BODIN and T. G. ROEFS, *IBM Washington Scientific Center, Wheaton, Maryland 20902.*

WEDNESDAY AM, NOVEMBER 6 CONNIE MACK ROOM

Session WA2: 9:00–11:30 AM

Techniques

WA2.1 **The Optimal Pseudo-Linear Classifier for a Multivariate Gaussian Discrimination Problem,** JOHN R. HOLDSWORTH, *Librascope,* and L. S. LUSTICK, *Department of Bio-Mathematics, Tulane University Medical School.*

WA2.2 **On the Use of Tchebychev Polynomials, Venn Diagrams, and Haase Diagrams in Operational Research,** Q. A. M. M. YAHYA, *Principal Research Officer, Defence Science Organization, Rawalpindi Laboratories.*

WA2.3 **Optimal Policies for a Stopped Markov Decision Problem,** DANIEL O. ETTER, JR., *Systems Evaluation Division, Institute for Defense Analysis, Arlington, Virginia.*

WA2.4 **Minimax Error Selection of a Discrete Univariate Distribution,** A. J. GOLDMAN, *National Bureau of Standards,* and P. R. MEYERS, *IBM World Trade Corporation.*

WA2.5 **An Algorithm to Solve Separable Constrained Optimization Problems,** EDWARD P. LOANE, *Daniel H. Wagner Associates, Paoli, Pennsylvania.*

WEDNESDAY AM, NOVEMBER 6 PENNSYLVANIA ROOM—EAST

Session WA3: 9:00–11:30 AM

Large Scale Business Systems

WA3.1 Forcol, A Command Language for Planning Data Manipulation, DONALD TIERNEY, and MILES WINBIGLER, *Commercial Airplane Division, The Boeing Company.*

WA3.2 Multi-Contract and Unbalanced Bidding Models, ROBERT M. STARK, and ROBERT H. MAYER, JR., *University of Delaware.*

WA3.3 Selection of Bank Loans for Evaluation: An Analytical Approach, YAIR E. ORGLER, *Federal Deposit Insurance Corporation, Washington, D. C.*

WA3.4 Cashflow Simulation for Evaluation Credit Risk on Corporate Bonds, V. H. KARMARKOV, *Philadelphia.*

WA3.5 A Decision and Value Theory Approach to a Manpower Allocation Problem, MARTIN L. CHILDS, *Command Systems Division, Communication and Systems, Inc., Virginia,* and HARVEY WOLFE, *Department of Operations Research and Systems Management Engineering, University of Pittsburgh.*

WA3.6 Resource Allocation, Two-Dimensional Constraints and Discrete Dynamic Programming, NORMAN R. BAKER, and JONATHAN S. YORMACK, *School of Industrial Engineering, Purdue University, Lafayette, Indiana.*

WEDNESDAY AM, NOVEMBER 6 DELAWARE VALLEY SUITE

Session WA4: 9:00–11:30 AM

Transportation Systems Efficiency

WA4.1 **The Minimax Transportation Problem,** A. J. GOLDMAN, *National Bureau of Standards, Washington, D. C.*

WA4.2 **Dynamic Transshipment Networks: An Algorithm and Its Application to the Distribution of Empty Containers,** WILLIAM W. WHITE *IBM Corporation, New York.*

WA4.3 **The Weighted One-Center Problem,** MYRON R. ROSENTHAL, *Illinois Institute of Technology, Chicago, Illinois.*

WA4.4 **A Mix-of-Modes Evaluation Model for Transportation Systems,** KEITH V. SMITH, *Cost Analysis Department, The Rand Corporation.*

WA4.5 **Discrete Optimization and Bayesian Sequential Search Procedures Applied to a Truck Routing Problem,** THOMAS W. BOLLAND, *Whittemore School of Business and Economics, University of New Hampshire.*

WA4.6 **Optimal Capacity of Dock Loading Facilities,** LELAND S. CASE, and LESTER B. LAVE, *Virginia Polytechnic Institute and Carnegie-Mellon University, Pittsburgh, Pennsylvania.*

WEDNESDAY AM, NOVEMBER 6 ROOM 540/546

Session WA5: 9:00–11:30 AM

Military Operations Research and Reliability

WA5.1 **Internal Warfare Model,** VERNON N. BEHRNS, *Marine Corps Operations Analysis Group.*

WA5.2 **A Min-Max Strategy for a Ballistic Missile Attack-Defense Game,** B. J. DUNN, P. H. RANDOLPH, G. E. SWINSON, *Braddock, Dunn and McDonald, Inc., El Paso, Texas.*

WA5.3 **Model and Historical Verification of the Labor Output of a U.S. Army Construction Battalion,** HORACE SCHOW, II, *U.S. Army Materiel Command, Systems Analysis Branch, Washington, D. C.*

WA5.4 **Models for Life Testing and Reliability Data,** ANDRE G. LAURENT, *Wayne State University, Detroit, Michigan.*

WA5.5 **Partitioning Electronic Equipment Through the Use of a Symptom-Matrix,** GRAFTON GRISWOLD, *ARING Research Corporation, Annapolis, Maryland.*

WA5.6 **A Stochastic Model for the Optimal Replacement of a Deteriorating Component System,** HARRY F. MARTZ, JR., and DAVID B. BROWN, *Texas Technological College.*

WA5.7 **Input-Output As An Aid to Military Decision Making,** RICHARD JENNER, and JOSEPH AUGUSTA, *Center for Naval Analyses.*

WEDNESDAY AM, NOVEMBER 6 ROOM 548/554

Session WA6: 9:00–11:30 AM

Scheduling and Forecasting

WA6.1 **Equipment Utilization Analysis by Simulation,** FROMAN HULBERT, *USAID-ADPA, Management Advisor to the Minister of Public Works, Republic of South Vietnam and Consultant to the Prime Minister's Committee for Administrative Improvement.*

WA6.2 **Combinatorial Analysis of JXM Sequencing Problems,** SAID ASHOUR, *Department of Industrial Engineering, Kansas State University.*

WA6.3 **Invariant Imbedding and Adaptive Forecasting,** E. STANLEY LEE, *Department of Industrial Engineering, Kansas State University.*

WA6.4 **Meta-Adaptive Modeling and Forecasting of Time-Series,** ARTHUR G. RAO, and ARTHUR SHAPIRO, *Operations Research Department, Mobil Oil Corporation.*

WA6.5 **Computer Generation and Plotting of Continuous Probability Distributions,** GENE A. FINKLER, *Management Science Services Department, Corn Products Company, New Jersey.*

WA6.6 **Degrees of Freedom and Degeneracy in Statistical Systems,** M. V. RAMA SASTRY, *Graduate School of Business Administration, University of Washington.*

WA6.7 **The Prediction of the Optimum Number of Simulation Trials and Simulation Values,** W. M. BASSIN, *The Stanwick Corporation.*

WEDNESDAY PM, NOVEMBER 6 PENNSYLVANIA ROOM—WEST (400)

Session WP: 12:30–1:50 PM

Speculations on the Year 2000: Tutorial 1

Speaker: Mr. Herman Kahn

WEDNESDAY PM, NOVEMBER 6 INDEPENDENCE ROOM

Session WP1: 1:50–4:40 PM

PROBLEMS OF IMPLEMENTING COMPLEX INDUSTRIAL SYSTEMS

Chairman: LAURANCE G. LOCKE, *Distribution Center, Eastman Kodak Company, Rochester, New York.*

WP1.1 ***Implementation of a Multi-location Large Scale Computer-Based Order Entry System,** THEODORE D. ROBBINS, *Distribution Center, Eastman Kodak Company, Rochester, New York.*

WP1.2 ***Some Psychological Problems Involved in Implementing Change in Organizations,** LANE RILAND, *Eastman Kodak Company, 343 State Street, Rochester, New York.*

WP1.3 ***Implementation in Operations Research and R & D: In Government and Business Operations,** MICHAEL RADNOR, ALBERT H. RUBENSTEIN, and DAVID A. TANSIK, *Northwestern University, Evanston, Illinois.*

WP1.4 ***Implementation of a Large Scale Production Distribution Planning System,** BRUCE R. BUZBY, and J. P. KELLY, *Union Carbide Corporation, New York, N. Y.*

WEDNESDAY PM, NOVEMBER 6 CONNIE MACK ROOM

Session WP2: 1:50–4:40 PM

Adaptive Models in Marketing

Chairman: PATRICK J. ROBINSON, *Marketing Science Institute, Philadelphia, Pa.*

WP2.1 ***An Adaptive Control Model for Partitioning a Population Between Two Treatments, Each of Whose Effectiveness Changes with Time,** JOHN D. C. LITTLE and JOEL SCHWIMER, *Sloan School of Management, MIT, Cambridge, Massachusetts.*

WP2.2 ***Some Adaptive Models for Sequentially Setting Advertising Budgets,** PETER T. FITZROY, *Wharton Scool of Finance and Commerce, University of Pennsylvania, Philadelphia, Pa.*

WP2.3 ***A Model for Diagnosing and Correcting Problems in New Product Introduction,** GLEN URBAN, *Sloan School of Management, MIT, Cambridge, Massachusetts.*

WP2.4 ***Adaptive Microsimulations of New Product Demand,** JEROME D. HERNITER, *Michigan State University, Lansing, Michigan* and VICTOR J. COOK, *Marketing Science Institute, Philadelphia, Pa.*

WEDNESDAY PM, NOVEMBER 6 PENNSYLVANIA ROOM—EAST

Session WP3: 1:50–4.40 PM

O.R. Applications to Space Systems Analysis

Chairman: JOE RAVENIS, *General Dynamics, Electronics Division, San Diego, California.*

WP3.1 ***Some Contributions in Dynamic Programming Techniques for Space Navigation Guidance and Control,** CORNELIUS T. LEONDES and FRED SMITH, *University of California.*

WP3.2 ***The Impact of Information Transfer Satellites on Everyday Living,** GEORGE E. FOSDICK and GEORGE W. MORGENTHALER, *Martin-Marietta Corporation, Denver, Colorado.*

WP3.3 ***Linear Programming Solutions for Orbital Transfer Trajectories,** CHARLES M. WAEPSY, *USAF, Directorate of Space, DCS/R&D, Washington, D. C.*

WP3.4 ***Outage and Replacement Implications for Operational Satellite Systems,** ROBERT A. DAVIS, *Aerospace Corporation, Los Angeles, California.*

WP3.5 ***Mathematical Model for Space Station Program Planning,** L. J. YORK, *Fort Worth Division of General Dynamics, Fort Worth, Texas.*

WEDNESDAY PM, NOVEMBER 6 CONSTITUTION ROOM

Session WP4: 1:50–4:40 PM

O.R. Theory—Military Applications

Chairman: WALTER L. DEEMER, *United States Arms Control and Disarmament Agency, Washington, D. C.*

WP4.1 ***Simple Models Useful in Allocating Aerial Interdiction Effort,** CLAYTON J. THOMAS, *HQUSAF, Washington, D. C.*

WP4.2 ***A Dynamic-Programming Approach to Populace Screening in Counterinsurgency Operations,** GLENN F. LINDSAY and ROBERT L. VOGT, *Naval Post Graduate School, Monterey, California.*

WP4.3 ***Fighter Aircraft Performance Modeling Simulation and Flight Testing for Research and Development,** TERRELL E. GREENE and R. L. SPICER, *The RAND Corporation, Santa Monica, California.*

WP4.4 ***The Roles of NIKE-X! An Integrated Weapons Systems Programming Model,** RONALD L. ARMS, JEROME BROCKEN, et al., *Research Analysis Corporation, McLean, Virginia.*

WEDNESDAY PM, NOVEMBER 6 ROOM 548/554

Session WP5: 1:50–4:40 PM

Systems Approach to Community Problems

Chairman: BOYD Z. PALMER, *Fels Institute of Local and State Government, University of Pennsylvania, Philadelphia, Pennsylvania*

WP5.1 ***Systems Analysis in Four Cities,** HAROLD MILLIE and W. EDWARD CUSHEN, *Technical Analysis Division, National Bureau of Standards, Washington, D. C.*

WP5.2 ***Time Sharing Use of Computers in Large Urban Governments,** NACHMAN BENCH, *Special Studies, Inc., New York, N. Y.*

WP5.3 ***Gaming-Simulation of Urban Decisions—The M.E.T.R.O. Project,** RICHARD DUKE, *School of Natural Resources, University of Michigan, Ann Arbor, Michigan.*

WEDNESDAY PM, NOVEMBER 6 ROOM 540/546

Session WP6: 1:50–4:40 PM

Information Storage and Retrieval

Chairman: MARY HAWES, *President, IFL Corporation, Philadelphia, Pa.*

Panel Members:

JOHN YOUNG, *NCR*

WEDNESDAY PM, NOVEMBER 6 DELAWARE VALLEY SUITE

Session WP7: 1:50–4:40 PM

Integer Programming

Chairman: EGAN BALAS, *Carnegie-Mellon University, Pittsburgh, Pennsylvania*

WP7.1 ***Combinatorial Programming,** GLEN GRAVERS, *Graduate School of Business, UCLA, Los Angeles, California* and ANDREW WHIRSTON, HERMAN C. KRUNNERT, *Graduate School of Industrial Administration, Purdue University, Lafayette, Indiana.*

WP7.2 ***Some Poly Hedra Related to Combinatorial Problems,** RALPH E. GOMORY, *IBM, Yorktown Heights, New York.*

WP7.3 ***Duality in Discrete Programming: IV Applications,** EGAN BALAS, *Carnegie-Mellon University, Pittsburgh, Pennsylvania.*

WP7.4 ***Faces of an Integer Polyhedron for Cyclic Groups—Part II,** FRED GLOVER, *University of Texas, Austin, Texas.*

WP7.5 ***Sentential Programming,** GERALD L. THOMPSON, *Carnegie-Mellon University, Pittsburgh, Pennsylvania.*

WP7.6 ***Turnpike Theorems for Integer Programming,** JEREMY F. SHAPIRO, *Massachusetts Institute of Technology, Alfred P. Sloan, School of Management, Cambridge, Mass.*

WEDNESDAY PM, NOVEMBER 6 PENNSYLVANIA ROOM—WEST (400)

Session WP: 4:40–6:00 PM

Speculations on the Year 2000: Tutorial 2

Speaker: Mr. Herman Kahn

THURSDAY AM, NOVEMBER 7 PENNSYLVANIA ROOM—WEST (400)

Session TA: 8:00–9:20 AM

Speculation on The Year 2000: Tutorial 3

Speaker: Mr. Herman Kahn

THURSDAY AM, NOVEMBER 7 INDEPENDENCE ROOM

Session TA1: 9:20 AM–Noon

Planning and Control of Research and Development—Part I

Chairman: LAWRENCE S. HILL, *The RAND Corporation, Santa Monica, California.*

TA1.1 ***Organization for Maintaining Individuality in a Team Situation in R&D,** E. C. HUGHES, *The Standard Oil Company (Ohio), Cleveland, Ohio.*

TA1.2 ***A Mathematical Basis for the Selection of Research Projects,** ARTHUR H. BOBIS, *American Cyanmid Company, Bourd Brook, New Jersey.*

TA1.3 ***Selection and Planning of Research and Development Projects,** J. F. MCCARTHY, JR. and R. L. STROM, *Space Division of North American Rockwell Corporation, Downey, Californa.*

TA1.4 ***Experience in Developing and Using a Planning and Control System in R&D Management,** WILLIAM E. SANDER, *Monsanto Company, St. Louis, Missouri.*

THURSDAY AM, NOVEMBER 7 CONNIE MACK ROOM

Session TA2: 9:20 AM–Noon

Mathematical Analysis of Perception and Preference

Chairman: PATRICK J. ROBINSON, *Marketing Science Institute, Philadelphia, Pa.*

TA2.1 ***Some Marketing Applications of Nonmetric Scaling Techniques,** PAUL E. GREEN, *University of Pennsylvania, Wharton School of Finance and Commerce.*

TA2.2 ***On Stability and Scenario Dependency of Perceptual and Preference Maps,** PATRICK J. ROBINSON, *Marketing Science Institute, Philadelphia, Pennsylvania,* and YORAM WIND, *Wharton School of Finance and Commerce, University of Pennsylvania, Philadelphia, Pa.*

TA2.3 ***A General Method for Preference Mapping of Perceptual Space,** J. DOUGLAS CARROLL, *Bell Telephone Laboratories, Murray Hill, New Jersey.*

THURSDAY AM, NOVEMBER 7 ROOM 540/546

Session TA3: 9:20 AM–Noon

Models of The Firm

Chairman: WILLIAM BRINKLOE, *University of Pittsburgh, Pittsburgh, Pennsylvania.*

TA3.1 ***Multi-Dimensional and Dynamic Models of Organization and Personnel Placement,** A. CHARNES, *The Technological Institute, Northwestern University, Evanston, Illinois;* W. W. COOPER, *Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, Pa.,* and A. STEDRY, *University of Texas.*

TA3.2 ***Organizational Response to Change,** JAMES A. VAUGHAN, *School of Business Administration, University of Rochester, Rochester, New York.*

TA3.3 ***Effect of Shift to Multiple Goals on the Model of a Public Agency,** IRWIN P. HALPERN, *NASA, Washington, D. C.*

TA3.4 ***The Effect of Market Diversification on Private Corporate Strategy,** JOHN J. HENRY, *North American Rockwell Corporation, Pittsburgh, Pennsylvania.*

THURSDAY AM, NOVEMBER 7 PENNSYLVANIA ROOM—EAST

Session TA4: 9:20 AM–Noon

*Operations Research Methodologies and Technologies for Space Sciences

Chairman: GLENN SELF, *Texas A&M University, College Station, Texas*

TA4.1 ***Mathematical Programming for Space Oriented Systems,** GLENN SELF, *Texas A&M University, College Station, Texas.*

TA4.2 ***Optimum Packaging Design and Spacing Levels for Extended Manned Space Missions,** DONALD WAGNER, *NASA/MSC.*

TA4.3 ***Space Station Experiments Program Analysis and Synthesis Routine,** J. L. HOWSE and T. E. PEUCE, *General Dynamics, Forth Worth, Texas.*

TA4.4 ***Methodology for Space Station Logistics Transportation Systems Analysis,** ROBERT G. VOSS, *NASA/HZ/OMSF,* and CUREY H. ROTLAND, *NASA/MSFC.*

TA4.5 ***Techniques for Estimating Program Completion Cost,** AUBIN O. FERGUSON, *NASA/MSC.*

THURSDAY AM, NOVEMBER 7 CONSTITUTION ROOM

Session TA5: 9:20 AM–Noon

The Diverse Views of the Role of C/E Analysis in Weapons and Force Selection

Chairman: MARTIN D. SCHWARTZ, *Autonetics, Anaheim, California.*

Panel Members:

RONALD L. EASLEY, *Director, Strategic Systems Review & Analysis, Office of Secretary of Defense (ODOR&E).*
R. NICHOLS HAZELWOOD, *Director, Analysis Laboratory, Data Systems Division, Litton Systems Inc.*
EDWARD P. OLIVER, *Chief, AFGOA/RAND, Special Study Group.*
JACOB A. STOCKFISCH, *Senior Research Associate, Institute for Defense Analyses.*

THURSDAY AM, NOVEMBER 7 ROOM 548/554

Session TA6: 9:20 AM–Noon

Human Resources

Chairman: ATHELSTON SPILHAUS, *Franklin Institute, Philadelphia, Pa.*

TA6.1 ***Human Resources Development,** BILLY BROWN, *Bureau of Employment Security, and* JEREMY LIFSEY and DAVID MILLER, *AUERBACH Corporation.*

TA6.2 ***An Equitable Method for Allocation of Youth to Achieve National Objectives,** BERNARD S. ALBERT, *General Electric, Missile and Space Division, Philadelphia, Pa.*

TA6.3 ***A Residential Land Use Prediction Model,** WALTER HELLY, *Polytechnic Institute of Brooklyn, Brooklyn, New York.*

TA6.4 ***Alternative Decision Rules for Educational Evaluation: A Simulation Analysis,** CHARLES SCHOTTA, JR., and CHARLES J. GETZ, *Virginia Polytechnic Institute.*

THURSDAY AM, NOVEMBER 7 DELAWARE VALLEY SUITE

Session TA7: 9:20 AM–Noon

Management Informations Systems

Chairman: ALAN HOFFMAN, *Frankford Arsenal, Philadelphia, Pa.*

TA7.1 ***Comparative Analysis of Current Management Information Systems,** MURRAY GREEN, *Communication and Information Systems, Cherry Hill, New Jersey.*

TA7.2 ***Methods of MIS Effectiveness,** STEPHEN W. LEIBHOLZ, *Analytics, Inc., Camden, New Jersey.*

THURSDAY PM, NOVEMBER 7 BALL ROOM—WEST

Session TPL: 12:00–1:45 PM

Round Table Luncheon

Chairman: GEORGE M. PARKS, *University of Pennsylvania, Philadelphia, Pennsylvania*

Each table will be chaired by a "name" personality to lead discussion on preannounced topic. Reservations for specific tables may be obtained at the registration desk.

THURSDAY PM, NOVEMBER 7 PENNSYLVANIA ROOM—WEST

1:45–2:30 PM

Orsa Special Business Meeting

THURSDAY PM, NOVEMBER 7 INDEPENDENCE ROOM

Session TP1: 2:30–5:15 PM

Planning and Control of Research and Development—Part II

Chairman: LAWRENCE S. HILL, *The RAND Corporation.*

TP1.1 ***System Design Criteria as Probabilities,** BENJAMIN OSTROFSKY, *TRW Systems, Redondo Beach, California.*

TP1.2 ***Toward a Method of Identifying Risk in Research and Development Tasks,** ROBERT D. DOERING, *Hughes Aircraft Company, Fullerton, California.*

TP1.3 ***Planning Research and Development Projects Using GERT,** A. ALAN B. PRITSKER and RONALD A. ENLOW, *Arizona State University, Tempe, Arizona.*

TP1.4 ***Deficiencies in Selected Control Systems with Special Reference to Research and Development,** ARTHUR W. GUTENBERG, *University of Southern California, Los Angeles, California.*

THURSDAY PM, NOVEMBER 7 ROOM 540/546

Session TP2: 2:30–5:15 PM

O.R. in Finance

Chairman: JAMES L. BICKSLER, *Ford Motor Company.*

TP2.1 ***The Optimal Bank Liquidity: A Multi Period Stochastic Model,** HANS DAELLENBACH and STEPHEN H. ARCHER.

TP2.2 **Valuation of New Product Proposals,** PETER D. BENNETT, EAMON M. KELLY and E. R. MELANDER.

TP2.3 ***Some Empirical Evidence on the Use of the Sharpe Portfolio Model to Predict Efficient Sets of Portfolios,** JAMES L. BICKSLER and JAMES MCGUIGAN.

THURSDAY PM, NOVEMBER 7 CONNIE MACK ROOM

Session TP3: 2:30–5:15 PM

O.R. in Pharmaceutical Industry

Chairman: MICHAEL LEYZOREK, *Merck & Co., Inc.*

TP3.1 ***Product Profit Optimization Considering the Managerial Decisions of Price, Marketing and Inventory,** DANA D. SQUIRE, *The Upjohn Company, Kalamazoo, Michigan.*

TP3.2 ***Sales Forecasting with an Adaptive Model,** HUGH E. BRADLEY, *The UpJohn Company, Kalamazoo, Michigan.*

TP3.3 ***Technical Planning,** DONALD T. ASHER, *Abbott Laboratories, North Chicago, Illinois.*

THURSDAY PM, NOVEMBER 7 ROOM 556/558

Session TP4: 2:30–5:15 PM

Operations Research in Engineering Design

Chairman: ROBERT M. STARK, *University of Delaware, Newark, Delaware.*

Panel Members:

RUSSELL L. ACKOFF, *University of Pennsylvania, Philadelphia, Pa.*
WILLIAM S. JEWELL, *University of California, Berkeley, California.*
(Others to be announced)

THURSDAY PM, NOVEMBER 7 PENNSYLVANIA ROOM—EAST

Session TP5: 2:30–5:15 PM

Workshop: O.R. Applications in Space Operations Management

Chairman: MICHAEL W. LODATO, *McDonnell Douglas Corporation, Huntington Beach, California.*

Participants:

LEO C. DRISCOLL, *Computer Research Laboratory, NASA Electronic Research Center, Cambridge, Mass.*
JONES W. ROACH, *Flight Control Division, NASA Manned Spacecraft Center, Houston, Texas.*
CHARLES HARLAN, *Flight Control Division, NASA Manned Spacecraft Center, Houston, Texas.*
Name to be determined, *Langley Research Center, NASA, Langley, Virginia.*

THURSDAY PM, NOVEMBER 7 ROOM 548/554

Session TP6: 2:30–5:15 PM

Cost-Effectiveness in Health

Chairman: ROBERT N. GROSSE, *Dept. of Health, Education and Welfare, Washington, D. C.*

TP6.1 ***Nursing Manpower Program Analysis,** JEFFREY H. WEISS, *Dept. of Health, Education and Welfare, Washington, D. C.*

TP6.2 ***The Technological Limit to Air Quality,** ELLISON S. BURTON and WILLIAM SANJOUR, *Ernst & Ernst, Washington, D. C.*

TP6.3 ***An Analysis and Comparison of the Provision of Pediatric Services,** GILBERT BERSTEIN, *Health Services Administration, City of New York, New York City.*

THURSDAY PM, NOVEMBER 7 DELAWARE VALLEY SUITE

Session TP7: 2:30–5:15 PM

Workshop in Simulation

Chairman: STEVE LEIBHOLZ, *Analytics, Inc., Camden, N. J.*

Panel Members:

JOHN DECANI, *Associate Professor of Operations Research and Statistics, University of Pennsylvania.*
FRANK MILILLO, *Head of Command Support Research Branch, U.S. Naval Research Laboratory.*
MORRIS PLOTKIN, *Associate Research Scientist, University of Pennsylvania.*
HAL TREMBLAY, *Chief of Computing and Simulation Division, U.S. Naval Air Development Center.*

THURSDAY PM, NOVEMBER 7 PENNSYLVANIA ROOM—EAST

5:15–5:45 PM

Space Science Section Business Meeting

THURSDAY PM, NOVEMBER 7 BALLROOM (400)

6:00– ? PM

Cocktail Party

FRIDAY AM, NOVEMBER 8 CONNIE MACK ROOM

Session FA1: 9:00–11:45 AM

O.R. Applications in the Chemical Industry

Chairman: STACEY N. ROWLEY, JR., *Control Division, Organic Chemicals Department, DuPont Company, Wilmington, Delaware.*

FA1.1 ***Process Optimization Using Nonlinear Programming,** HENRY J. MORRIS, *Monsanto Company, St. Louis, Missouri.*

FA1.2 ***Determination of Near-Optimal Policies by State Variable Approximation,** R. L. ZAHRADNIK, *Carnegie-Mellon University, Pittsburgh, Pennsylvania.*

FA1.3 ***Results and Methods in the Risk Oriented Investment Decision,** ARTHUR STEVENKEL, *Corn Products, Englewood Cliffs, New Jersey.*

FA1.4 ***Design of Corporate Strategic Studies,** ROBERT B. GRANT, *Celanese Corporation, New York, New York.*

FA1.5 ***The Role of Cardinal Utility Theory in Decisions Under Risk,** RALPH O. SWALM, *Syracuse University, Syracuse, New York.*

FRIDAY AM, NOVEMBER 8 ROOM 556/558

Session FA2: 9:00–11:45 AM

Transportation Section—Invited Papers

Chairman: DONALD CAPELLE, *Alan M. Voorhees and Assoc., Inc., McLean, Virginia.*

FA2.1 ***Speed Estimation from a Moving Automobile,** LEONARD EVANS, *General Motors Research Laboratory, Warren, Michigan.*

FA2.2 ***Highlights of the Fourth International Symposium on the Theory of Traffic Flow,** RICHARD ROTHERY, *General Motors Research Laboratory, Warren, Michigan.*

FA2.3 ***An Analysis of the Boltzmann-Type Statistical Models for Multi-Lane Traffic Flow,** P. MUNJAL, *System Development Corporation, Santa Monica, California.*

FA2.4 ***Case Study in the Application of a Traffic Network Simulation Model,** FRANK C. BARNES and FREDERICK A. WAGNER, JR., *Planning Research Corporation, Los Angeles, California.*

FA2.5 ***Increasing Expressway Utilization for Motorists,** RICHARD H. HAASE, *College of Business Administration, Drexel Institute of Technology, Philadelphia, Pennsylvania.*

FRIDAY AM, NOVEMBER 8 DELAWARE VALLEY SUITE

Session FA3: 9:00–11:45 AM

Vietnam Applications

Chairman: RICHARD J. SWERSEY, *University of Pennsylvania, Philadelphia, Pennsylvania.*

FA3.1 ***Applying Metagame Theory to the Vietnam Conflict,** NIGEL HOWARD, *Management Science Center, University of Pennsylvania, Philadelphia, Pennsylvania.*

FA3.2 ***Optimizing Strike Force Planning,** PAUL L. GRAY, *Operations Analysis Office, USAF, Washington, D. C.*

FA3.3 ***Optimal Allocation of Air Strikes for Interdiction of a Transportation Network,** THOMAS M. MUSTIN and ALAN W. MCMASTERS, *Dept. of Operations Analysis, Naval Postgraduate School, Monterey, California.*

FA3.4 ***Time Dependent Predictions of Guerilla Actions,** RICHARD S. MOREY, *Stanford Research Institute, Menlo Park, California.*

FA3.5 ***Logistics Support Alternatives for Combat Fighter Wings.** CHARLES L. MOOR and JAY WILLIAMS, *Operations Analysis Office, Air Force Logistics Command, Washington, D. C.*

FRIDAY AM, NOVEMBER 8 ROOM 540/546

Session FA4: 9:00–11:45 AM

Opportunities in Education

Chairman: ROGER SISSION, *University of Pennsylvania, Philadelphia, Pennsylvania.*

FA4.1 ***Common Patterns in Educational Planning Models,** JOSE GLASSERMAN, *IBM, 2651 Strong Blvd., Yorktown Heights, New York.*

FA4.2 ***Cost-Effectiveness Analysis and Educational Policy—Profusion, Confusion, Promise,** HENRY M. LEVIN, *The Brookings Institute, 1775 Mass Avenue, N.W., Washington, D. C.*

FA4.3 ***Adaption of PPBS to a Decentralized Management Strategy,** OLIVER S. BROWN, *Board of Education, School District of Philadelphia, Philadelphia, Pennsylvania.*

FRIDAY AM, NOVEMBER 8 ROOM 548/554

Session FA5: 9:00–11:45 AM

New Techniques and Applications of Operations Research

Chairman: SAMUEL MATLIN, *General Electric Company RSD, Valley Forge, Pa.*

FA5.1 ***The Application of OR to Criminal Justice,** ALFRED BLUMSTEIN, *Institute for Defense Analysis, Arlington, Virginia.*

FA5.2 ***The DELPHI Method,** N. DALKEY, *The RAND Corporation, Santa Monica, California.*

FA5.3 ***Application of O.R. to R&D Management,** BURTON V. DEAN, *Case Western Reserve University, Cleveland, Ohio.*

FA5.4 ***The Probabilistic Aspects of Long Range Planning,** DAVID B. HERTZ, *McKinsey & Co., Inc., New York, New York.*

FA5.5 ***Optimal Sequencing of Jobs Subject to Deadlines,** E. LAWLER and J. M. MOORE, *University of Michigan, Ann Arbor, Michigan.*

FA5.6 ***Theory and Application of Generalized Polynominal Optimization'** DOUGLAS J. WILDE, *Stanford University, Stanford, California.*

FRIDAY AM, NOVEMBER 8 INDEPENDENCE ROOM

Session FA6: 9:00–11:45 AM

Aerospace Systems

FA6.1 **A Computerized Cost Model for Space Systems,** LEONARD Y. SHAKT, *Missile and Space Division, General Electric Company, King of Prussia, Pennsylvania.*

FA6.2 **Probability of Biological Contamination of Mars,** ANDREW UNGAR, *Matson Research Corporation, San Francisco, California.*

FA6.3 **Methods of Optimizing Satellite Communications Networks,** GEORGE E. BOWDEN, ROBERT C. MOORE, WILLIAM R. MINTY, *Philco-Ford Corporation.*

FA6.4 **Cost Effective Selection for a National Space Launch Vehicle Stable,** ROBERT E. DROWNS, *Advanced Applications, LVP, General Dynamics/Corvair, San Diego, California.*

FA6.5 **A Nondemographic Factor V/STOL Prediction Model,** ALEXIS N. SOMMERS, and FERDINAND F. LEIMKUHLER, *School of Industrial Engineering, Purdue University, Lafayette, Indiana.*

FA6.6 **A Scheduling Technique Applicable to Manned Earth Orbiting** SOMMERS, *Vitro Labs., Silver Spring, Maryland,* and FERDINAND F. LEIMKUHLER, *School of Industrial Engineering, Purdue University, Indiana.*

FRIDAY, NOVEMBER 8 PENNSYLVANIA ROOM—WEST (250)

11:45–1:30 PM

Long Range Planning Committee Meeting & Luncheon

Chairman: THOMAS E. OBERBECK

Guest Speakers:

CLINTON P. ANCKER, JR., *Chairman (1967–1968).*
FRED S. HOFFMAN, *Assistant Director, Bureau of the Budget.*

FRIDAY PM, NOVEMBER 8 ROOM 548/554

Session FP1: 1:30–4:00 PM

Operations Research in Insurance

Chairman: GORDON D. SHELLARD, *New York Life Insurance Company, 51 Madison Avenue, New York, New York.*

FP1.1 ***Prices and Profits,** JOHN M. BRAGG, *Life Insurance Company of Georgia, 600 West Peachtree Street, N.W., Atlanta, Georgia.*

FP1.2 ***Prices and Profits in the Property and Liability Insurance Industry,** DAVID M. BOODMAN and IRVING H. PLOTKIN, *Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts.*

FP1.3 ***Collective Risk Theory,** PAUL M. KAHN, *Equitable Life Assurance Society of the United States, 1285 Avenue of the Americas, New York, New York.*

FP1.4 ***A Flood Insurance Model,** TAPAN ROY, *The Travelers Insurance Company, 1 Tower Square, Hartford, Connecticut.*

FP1.5 ***Optimizing Debit Size,** DWIGHT K. BARTLETT, III, *Monumental Life Insurance Company, Charles & Chase Streets, Baltimore, Maryland.*

FRIDAY PM, NOVEMBER 8 CONNIE MACK ROOM

Session FP2: 1:30–4:00 PM

O.R. in the Petroleum Industry

Chairman: ROBERT A. FRANZONI, *Sun Oil Company, Philadelphia, Pa.*

FP2.1 ***Simulation of a Private Line Communications Network and A Real Time Management Information System Network,** MARVIN AMES, *Sinclair Oil Corporation.*

FP2.2 ***Seeking of Optimum Well Spacing and Production Systems in Oilfields,** P. MUNJAL, *System Development Corporation, Santa Monica, California.*

FP2.3 ***Reservoir Simulation Models,** RUDOLPH W. BUCHWALD, THOMAS L. SPRATT, and HOWARD L. TAYLOR, *Sun Oil Company, Philadelphia, Pennsylvania.*

FRIDAY PM, NOVEMBER 8 ROOM 556/558

Session FP3: 1:30–4:00 PM

Cost Benefits in Transportation

Chairman: ALLEN H. SKAGGS, *Office of Secretary of Transportation, Washington, D. C.*

FP3.1 ***Cost/Benefit Analysis Applied to the Design of Commercial Air Transport-Type Aircraft,** G. A. BUSCH, *Lockheed Aircraft Corporation, Burbank, California.*

FP3.2 ***Program Structure and Cost/Benefit Analysis in Transportation,** ALLEN FERGUSON, *Planning Research Corporation, Washington, D. C.*

FP3.3 ***The Northeast Corridor: A Comprehensive Systems Analysis,** ROBERT A. NELSON, *Federal Railroad Administration, Washington, D. C.*

FRIDAY PM, NOVEMBER 8 PENNSYLVANIA ROOM—EAST

Session FP4: 1:30–4:00 PM

O.R. in the Aerospace Industry

Chairman: HAROLD C. SEBRING, *Office of the Assistant Vice Chief of Staff, Force Planning Analysis, U.S. Army, Washington, D. C.*

FP4.1 ***Pen Aids Optimization Model,** KENNETH E. SHANK, *Raytheon Company, Sudbury, Massachusetts.*

FP4.2 ***Evaluation Subsystems for the Defense of a Strike Aircraft,** J. A. BOOSE, *IBM, Federal Systems Division, Owega, New York.*

FP4.3 ***Defense Penetration Systems Optimization,** JOHN E. PUTRUCCI, JR., *Grumman Aircraft Engineering Corp., Bethpage, New York.*

FP4.4 ***An Aircraft Squadron Performance Effectiveness Model,** LAWRENCE A. FEIDELMAN, *AUERBACH Corporation, Philadelphia, Pa.*, and LEO ROGIN, *Naval Air Development Center, Johnsville, Warminster, Pa.*

FRIDAY PM, NOVEMBER 8 ROOM 540/546

Session FP5: 1:30–4:00 PM

O.R. in Education

Chairman: DAVID S. STOLLER, *U.S. Office of Education, National Center for Education Statistics, Washington, D. C.*

FP5.1 **Evaluation of Educational Programs: A Systems Approach,** MARTIN I. TAFT, *California State College at Los Angeles, Los Angeles, California*, and ARNOLD REISMAN, *Case Western Reserve University, Cleveland, Ohio.*

FP5.2 **An Analysis of Teacher Supply and Demand in California,** ANTON S. MORTON, *Arthur D. Little, Inc., Cambridge, Mass.*

FP5.3 **On Attempting to Relate the Inputs and Outputs of Institutions of Higher Education,** RICHARD J. O'BRIEN, and JUDITH ZINTON, *U.S. Office of Education, Washington, D. C.*

FRIDAY PM, NOVEMBER 8 INDEPENDENCE ROOM

Session FP6: 1:30–4:00 PM

Production and Distribution Management

FP6.1 **A Mathematical Model for the Optimization of a Generlaized Waste Management System,** LOREN E. ANDERSON, *Commercial Airplane Division, The Boeing Company, Washington, D. C.*

FP6.2 **Forecasting for Production Planning,** STEPHEN S. LAZARUS, *College of Business Administration, University of Rochester, Rochester, New York.*

FP6.3 **An Algorithm for the Planning and Optimization of a Rough Turning Operation,** P. BRUCE BERRA, *Dept. of Industrial Engineering, Syracuse University, Syracuse, New York,* and MOSHE M. BARASH, *School of Industrial Engineering, Purdue University, Lafayette, Indiana.*

FP6.4 **A Cost Effectiveness Model of Hospital Pharmacy Inventory, and Drug Utilization Systems,** PAUL M. WOOD, *Travelers Research Center, Hartford, Connecticut.*

FRIDAY PM, NOVEMBER 8 DELAWARE VALLEY SUITE

Session FP7: 1:30–4:00 PM

The Traveling Salesman Problem

FP7.1 **A Practical Algorithm for Finding Solutions to the Traveling Salesman Problem,** RICHARD E. OBERUC, *Uncle Ben's Incorporated, Houston, Texas.*

FP7.2 **Pathology and Therapy for Traveling Salesman Algorithms,** M. BELLMORE, *Johns Hopkins University,* and J. C. MALONE, *Bell Telephone Laboratories, New Jersey.*

FP7.3 **A Method of Solving Traveling Salesman Problems,** D. K. GUHA, *The Port of New York Authority.*

ABSTRACTS

WA1.1 Air Pollution Abatement Models, ELLISON S. BURTON, WILLIAM SANJOUR, and RICHARD L. ANDERSON, Ernst & Ernst, 900 17th Street, Washington, D. C. 20006.

In the past year, Ernst & Ernst has produced several studies of air pollution abatement by simulating urban areas and the effects of various abatement strategies on emissions, air quality, and human exposure. Among the strategies which have been evaluated are: limiting the sulfur content of fuels, emission controls, tax incentives, and maximum reduction. We have also developed a computer program, which pushes the state of the art of zero-one programming to find the lower limit or least cost solution to any air quality objective. When the above strategies are compared with the least cost solution which achieves the same goal, it is found that the least cost solution is usually considerably cheaper. This paper will discuss the reasons for this and the ways of developing strategies which are both legislatable and enforceable, and yet comparable in cost to the least cost solutions.

WA1.2 Absorbing Markov Chain Models Applied to Blood Bank Problems, C. CARL PEGELS, *Assistant Professor of Management Science,* and ANDREW JELMERT, *Instructor in Management Science, State University of New York At Buffalo, N. Y.*

The theory of Absorbing Markov Chains has been applied to three blood bank problems. In the first two problems the non-absorbing states consist of the age of blood in days; in the last problem the nonabsorbing states consist of conditional probabilities that blood if assigned will be transfused. After manipulations and vector multiplications of the matrices, answers are provided to such questions as expected age of blood at transfusion, expected number of units expired, expected number of days until blood in a given state will be transfused, and probability that blood in a given state will be transfused.

WA1.3 An Application of Integer Programming for Legislative Redistricting, W. H. WAGNER, *Management Services, Union Carbide Corporation, New York and CROND, Inc., Wilmington, Delaware.*

This paper describes an application of Operations Research to the problem of legislative redistricting in which the purpose was to develop a practical algorithmic formulation and solution method. A new integer programming formulation of the redistricting problem is presented with certain characteristics which give hope to practical solution methods. A unique column generation procedure is able to define all of the possible columns of the integer programming problem by a branch-and-bound type tree search. Computational experience using several mixed integer

and zero-one programming codes is given with the linear programming based methods uniformly superior to the non-LP based methods. Conclusions are made with respect to specific algorithms and/or improvements seem to be required to solve such problems routinely.

WA1.4 Nonlinear Programming Approach to the Optimization of a Generalized Reservoir System, L. D. BODIN and T. G. ROEFS, *IBM Washington Scientific Center, Wheaton, Maryland 20902.*

An important problem in the management of a reservoir system is to determine the volume of water to release from each reservoir over time in order to maximize benefits. The probability distribution of streamflow inputs, the operation targets, the benefit functions, and the physical characteristics of the system are known. By sampling from these inflow distributions, one can formulate this problem as a nonlinear program. However, by utilizing the special structure of the constraint set and solving the nonlinear equations in the subproblems, the Dantzig Wolfe decomposition principle can be applied to derive a nearly optimal solution to the problem. By repeating this procedure for several inflow patterns and performing a regression analysis on the results of these trials, an approximate operating policy over the entire set of possible inflows is derived.

WA2.1 The Optimal Pseudo-Linear Classifier for a Multivariate Gaussian Discrimination Problem, JOHN R. HOLDSWORTH, SR. *Staff Engineer, Librascope,* and L. S. LUSTICK, *Department of Bio-Mathematics, Tulane University Medical School.*

In many operations research problems, an integral subcomponent is a detection or classification problem which can sometimes be cast as a classical test of a statistical hypothesis. A particular example, which recently arose in the design of an automotive diagnostic sensor configuration, is the classification of a vector valued observation into one of two known multivariate gaussian distributions with equal mean vectors. When testing the multivariate hypothesis $H_0: x \sim N(\mu_0, \Sigma_0)$ against the alternative $H_1: x \sim N(\mu_1, \Sigma_1)$, where x is an nxl observation vector and μ_0, Σ_0, μ_1, Σ_1 are the mean vectors and covariance matrices assumed known under the two hypotheses, then when $\Sigma_0 \neq \Sigma_1$, the likelihood ratio yields an indefinite quadratic form as a test statistic, whose distribution under both the null and alternative hypotheses is extremely difficult if not practically impossible to compute. In a recent paper: "Classification Into Two Multivariate Normal Distributions with Different Covariance Matrices", Annals of Mathematical Statistics, Vol. 33, No. 2, Anderson and Bahadur consider the problem of determining the best "linear" statistic $y = \vec{b}^T x$ with a one sided threshold which uses information obtained just from the mean separation, so that detection is maximized for a given false alarm level. The present paper shows that the problem where the means are equal may be solved exactly using a pseudo-linear statistic of the same form with a two sided threshold, which obtains its resolving power from the covariance matrices.

It is shown that the detection versus false alarm curve is always concave and that perfect detectability is achieved for arbitrarily small false alarm rates for the various singular cases in which the truly optimal Neyman Pearson classifier performs perfectly. Numerical examples exhibit cases where the improvement over the Anderson Bahadur classifier is quite dramatic.

WA2.2 On the Use of Tchebychev Polynomials, Venn Diagram and Hasse Diagrams in Operational Research, Q. A. M. M. YAHYA, *Principal Research Officer, Defense Science Organization, Rawalpindi Laboratories.*

It is discussed how Tchebychev Polynomials can help in the calculation of typical O.R. models and data analysis. In particular, by converting into a power series, the steps of economization show the advantage of this technique over least-squares fit or similar methods. The second part of this paper shows that the Venn Diagrams (also called Euler Diagram), and Hasse Diagrams not only verify all valid syllogism but can be tactfully employed in setting Operational Research objectives for most practical O.R. problems. The work is a continuation of similar work taken up earlier (Yahya, Bull. Oper. Res. Soc. Amer. Vol 15 (1967). p. B-90).

WA2.3 Optimal Policies for a Stopped Markov Decision Problem, DANIEL O. ETTER, JR., *Systems Evaluation Division, Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia 22202.*

Consider a Markov chain with rewards, as discussed by Howard [Dynamic Programming and Markov Processes, Technology Press, 1960]. Assume that the admissible transition matrices all lead to recurrent chains. The usual analyses require either the use of discounting to force convergence or the assumption that the process continues forever. We point out a third approach here, in which the basic process is paired with an independent Markov process which determines when the basic process is stopped. The stopped process can be considered to be a transient chain; the analysis is carried out in the context of the potential theory for such chains. We show the relationship between the results obtained this way and those obtained using both discounting and infinite-horizon approaches.

WA2.4 Minimax Error Selection of a Discrete Univariate Distribution, A. J. GOLDMAN, *National Bureau of Standards, Washington, D.C. 20234,* and P. R. MEYERS, *IBM World Trade Corporation, New York, N.Y. 10017.*

The topic treated is that of finding a reproducible, plausible and computationally simple method of selecting a discrete frequency distribution with prescribed upper and lower bounds on its components. The problem is shown to be tractable when a minimax error selection criterion is employed, and "error" is measured by maximum absolute deviation between components. In this case one obtains a linear program of a special form admitting explicit solution. The vertices of the polyhedron of optimal solutions can also be found explicitly, and so their centroid can be calculated if unique specification is required.

WA2.5 An Algorithm to Solve Finite Separable Constrained Optimization Problems, EDWARD P. LOANE, *Daniel H. Wagner, Associates, Paoli, Pennsylvania.*

An iterative algorithm is presented which allows the solution to the following problem to be obtained to any desired degree of accuracy: choose $x_i \epsilon A_i$ for $i=1,\cdots,n$ to minimize $\sum_{i=1}^{n} c_i(x)$ subject to $\sum_{i=1}^{n} e_i(x) \geq E$ for arbitrary given real E, c_i, e_i, and finite A_i, $i=1,\cdots,n$. In particular the sets $\{(c_i(\gamma), e_i(\gamma)) : \gamma \epsilon A_i\}$ need not be convex. The procedure offers considerable computational advantage over alternative means of obtaining the desired solution. The technique uses a pair of Lagrange multipliers for the single constraint. The pair of Lagrangrians induce a partial ordering among the set of all $(x_1,\cdots,x_n)$. The desired solution is to be found among the maximal elements under this ordering for appropriate choices of the multipliers, and possible improvement in the solution is bounded in terms of other maximal elements. The set of all maximal elements, under partial ordering, is generated by a dynamic programming algorithm.

WA3.1 FORCOL, A Command Language for Planning Data Manipulation, DONALD TIERNEY and D. MYLES WINBIGLER, *The Boeing Company, Commercial Airplane Division.*

The collection, manipulation, modification, update, and display of large sets of time oriented data streams is a familiar problem to the planning departments of large corporations. The magnitude of the data manipulation problem makes a timely response to a changing environment quite difficult, if not impossible. This paper discusses the development and implementation of FORCOL, a miniature compiler of a command language written for the CDC 6600, which can free the planner from much of his desk calculator activity. FORCOL consists of three major parts: a descriptor (or keyword) structure for data retrieval and a permanent data base, both defined by the user; and a command language. The command language is simple in structure and is designed for use by non-computer oriented people. It includes commands to perform algebraic operations and certain simple statistical procedures, and to generate both printed and graphical reports. All user programming is free form with few required conventions and formats in operations, input, or report generation.

WA3.2 Multi-Contract and Unbalanced Bidding Models, ROBERT M. STARK and ROBERT H. MAYER, JR., *University of Delaware, Newark, Delaware.*

Friedman's (1956) model with an expected profit objective is extended to several contracts (with and without cost interaction) using mathematical programming techniques. The practice of unbalanced bidding is identified (for unit price proposals). The model is formulated with a present worth of future revenue objective. A simple linear programming form emerges.

WA3.3 Selection of Bank Loans for Evaluation: An Analytical Approach, YAIR E. ORGLER, *Federal Deposit Insurance Corporation, Washington, D. C. 20429.*

Among the many responsibilies of bank management and bank regulatory agencies, the periodic evaluation of bank loan portfolios stands out in importance and complexity. Since it is both unnecessary and impractical to evaluate every bank loan, the loan evaluation problem may be divided into two parts: 1) Selection of loans for evaluation, and 2) Evaluation of the selected loans. The purpose of this paper is to suggest an analytical method for solving the selection problem. Our approach is based on a linear programming model which determines optimal sample sizes for a stratified sampling plan. The model provides explicit and simultaneous control over time, coverage and other relevant aspects of the evaluation process. The results of the evaluation may then be projected to provide bank auditors, loan officers, and examiners with a meaningful measure of quality for the entire loan portfolio.

WA3.4 Cashflow Simulation for Evaluating Credit Risk on Corporate Bonds, V. H. KARMARKOV, *247 South 38th St., Philadelphia, Pa. 19104.*

Financial institutions such as insurance companies and pension trusts lend money to several corporations. For this purpose borrower's creditworthiness is assessed by analyzing past financial and operating data, and by studying such factors as management capacity, labor relations, outlook for the industry. The conventional techniques rely heavily on historical performance. Projection into the future is given relatively less weight. The techniques also do not provide a comprehensive framework by which the effects of all the important factors affecting a borrower's creditworthiness can be studied and good points of one factor can be traded off against the bad points of the other. Cashflow simulation technique described in the paper provides the required framework and enables a creditor to determine the probability that a borrower will fail to generate cashflow $\geq$ annual fixed charges plus a margin of safety in m out of an n-year sequence. m, n and safety margin are to be given by the creditor depending on his willingness to assume risk. The cashflow model is based on empirical financial data which are readily available. But it may be modified to allow for anticipated changes in historical relations.

WA3.5 A Decision and Value Theory Approach to a Manpower Allocation Problem, MARTIN L. CHILDS, *Command Systems Division, Communications and Systems Inc., Falls Church, Virginia,* and HARVEY WOLFE, *Department of Operations Research and Systems Management Engineering, University of Pittsburgh, Pittsburgh, Pennsylvania.*

A problem which exists in a large research laboratory is the allocation of professional people to work on research projects. Each department manager must allocate his personnel so that effectiveness, value of a given man to a given project, is maximized. Computationally, the transportation technique may be used to solve the problem if it is possible to determine the individual coefficients (or effectiveness values) giving the relative value of the i'th man to the j'th project, for

all i, j. This paper describes a technique for determining these effectiveness values. The effectiveness values are subjective, and reflect the value judgments of the department manager, and a project board. The philosophy used in producing the effectiveness values is to simplify the manager or board member's decision-making task in expressing his value judgments to comparing only two alternatives with respect to a single criteria at one time. The results of the ratings taken are mathematically reduced to produce a set of normalized effectiveness values. The use of the technique in a model allocation problem is shown. The application of the technique need not be confined to a manpower allocation problem, but can be applied to any resource allocation problem where the objective is to maximize a subjective measure.

WA3.6 Resource Allocation Two-Dimensional Constraints and Discrete Dynamic Programming, NORMAN R. BAKER, and JONATHAN S. YORMARK, *School of Industrial Engineering, Purdue University, Lafayette, Indiana 47907.*

This paper considers the allocation of a scarce resource when the allocation is simultaneously restricted by constraints on two entities, e.g., when both time period and activity constraints are imposed. The major assumption is that return from an allocation to an activity during a single time period is independent of allocations made to the same activity during other time periods or to other activities during the same or other time periods. This two-dimensional resource allocation problem is formulated as a discrete dynamic programming problem, a (0, 1) programming problem, and a capacitated transportation problem. The assumptions underlying each formulation are made explicit. Optimal dynamic programming procedures are developed for certain partially constrained forms of the problem and are shown to solve analogous classes of (0, 1) programming problems. The general two-dimensional problem remains unsolved; however, an upper bound on the value of the objective function has been found, an iterative search solution procedure has been suggested, and two promising search algorithms are being evaluated.

WA4.1 The Minimax Transportation Problem, A. J. GOLDMAN, *National Bureau of Standards, Washington, D. C. 20234.*

Given a set of origins each with a known supply of some commodity, and a set of destinations each with a known demand, the problem is to find the smallest possible capacity for a vehicle which is to perform the origin-to-destination transfers one at a time. A simple solution method is demonstrated for this problem, which mathematically is that of choosing a non-negative matrix with prescribed row and column sums so as to minimize its largest entry.

WA4.2 Dynamic Transshipment Networks: An Algorithm and Its Application to the Distribution of Empty Containers, WILLIAM W. WHITE, *IBM Corporation, 410 East 62nd Street, New York, New York.*

The movement of vehicles and goods in a transportation system can be represented as flows through a time-dependent transshipment network. An inductive out-of-kilter type of algorithm is presented which utilizes the basic underlying

properties of the dynamic transshipment network to optimize the flow of a homogeneous commodity through the network, given a linear cost function. The algorithm is illustrated by its application to the problem of distributing empty containers from locations at which they are available to locations at which they are required.

WA4.3 The Weighted 1-Center Problem, MYRON R. ROSENTHAL, *Assistant Professor of Mathematics, Illinois Institute of Technology, Tech Center, Chicago, Illinois 60616.*

The center of a graph is defined to be that point lying on the graph which minimizes the maximum distance to any vertex of the graph. A more general problem evolves when one allows the vertices, as well as the branches, to have positive weights. In this way weights on the branches could represent transportation costs while weights on the vertices could represent demand. When considered in this light, the solution of the weighted center problem can be used as an approximation to solving the location-allocation problem. A method is illustrated in this paper whereby one may determine the branch which contains the center in step one and then find the center on that branch in step two. An upper limit on the number of calculations necessary is stated as well as an average number of calculations and an example.

WA4.4 A Mix-of-Modes Evaluation Model for Transportation Systems, KEITH V. SMITH.

A benefit-cost model is presented for determining the optimal choice among alternative transportation systems—each an improvement of the basic transportation system which is postulated to be operational during a planning horizon of several years. Although the model is developed for travel between two cities, it can be extended to a full network of many cities. Each transportation system consists of several inter-city major transportation modes as well as intra-city feeder modes. Relative benefits and costs are considered for travelers, operating firms, and the general public along selected attribute dimensions. Important variables include the expected demand for trips between the two cities, measures of value for each attribute and mode combination, and various discounting and weighting parameters. A sensitivity analysis is suggested for testing the responsiveness of the evaluation model to individual and joint changes in these variables and parameters. The benefit-cost model and sensitivity analysis are illustrated using an hypothetical example which involves two alternative changes to a basic system consisting of seven modes and four attribute dimensions over a planning horizon of five years.

WA4.5 Discrete Optimization and Bayesian Sequential Search Procedures Applied to a Truck Routing Problem, THOMAS W. BOLLAND, *Whittemore School of Business and Economics, The University of New Hampshire, Durham, New Hampshire, 03824.*

Using and refining concepts included in Discrete Optimizing, as developed by Reiter and Sherman and their disciples, several solution procedures have been devised, programmed and used to solve a series of truck routing problems (alias "commercial" truck dispatching problems, alias delivery problems). Since these procedures have a significant Bayesian flavor in them the problems were also solved

using "pure" Bayesian sequential search procedures. Based upon the results obtained and using heuristic programming criteria a comparison is made as to the relative optimality of these two types of solution procedures to solve such problems. (In using either type of solution procedure the effective randomization of the solution spaces relative to the search procedures was assumed.) A further comparison of this same nature is made with previously developed, deterministic heuristic solution methods. And finally, the sensitivity of the quality of results, using the Discrete Optimizing procedures, to changes in the values of several key input variables is explored.

WA5.1 Internal Warfare Model, VERNON N. BEHRNS, *Marine Corps Operations Analysis Group.*

The purpose of this model is to assess the impact of introducing various sized friendly forces, with associated roles and capabilities into a insurgency combat area. Its primary output is surviving enemy (insurgent) force level as a function of time. The model is aggregated in that it employs precalculated Revolutionary Development and Attrition Capability estimates for the various categories of friendly troops and treats combat zones (of the combat area) as units of area for purposes of population control and enemy attrition calculations. The enemy troop movements considered are of two kinds: infiltrators and unit transfers. A source of enemy troops exterior to the combat area is included in addition to the recruitment sources within the combat zones. The enemy troop movements are partially determined on the basis of maintaining preselected force ratios and partially by prescheduled inputs. Moving enemy troops are subject to attrition while enroute. The size of the enemy force (in each combat zone) at the end of the nth month is determined by: the enemy force level at the end of the previous month the within month recruitment, infiltration, and net transfer of troops and the departures and within zone attrition during the nth month.

WA5.2 A Max-Min Strategy for a Ballistic Missile Attack-Defense Game. B. J. DUNN, P. H. RANDOLPH, and G. E. SWINSON, *Braddock, Dunn and McDonald, Inc., Braniff Road, El Paso, Texas.*

This paper presents the results and method of analysis for a particular two person game that arises in ballistic missile attack-defense problems. Each player is assumed to have a fixed stockpile of a given type of resource to be allocated to a specified set of targets. The optimality criteria for both players is the "expected value destroyed" resulting from given attack-defense postures. Under the assumption of perfect attackers and imperfect defenders, this payoff function does not exhibit the usual niceties of convexity or continuity. In this paper, particular emphasis is placed on the development of a model which is suitable for computer formulation.

WA5.3 Model and Historical Verification of the Labor Output of a US Army Construction Battalion, HORACE SCHOW II, *Headquarters, US Army Materiel Command, Systems Analysis Branch, Room 2512, Washington, D.C 20315.*

This paper presents a model which yields the predicted labor output of a US

US Army construction battalion. The output is defined as the weekly number of man-hours directly expended on construction-type activities. An analysis is given which shows that 76 workers out of a company strength of 178 men and 273 workers out of a battalion of 850 men should be directly committed to construction projects. The remainder of the men are occupied with indirect construction support, administration, and community overhead activities. The objective function, the Construction Ratio, is defined as the actual over the predicted number of man-hours on construction projects per week. The verification is based upon historical data taken from two construction seasons in northeastern France where the average Construction Ratio was computed to be 0.83. The correction is adjust for an understrength unit is given. Although the estimates given are for a specific type of construction battalion, the methodology is general and can be applied to other units. The authors comments on his recent experience with a construction battalion is Vietnam.

WA5.4 Models for Life Testing and Reliability Data, ANDRE G. LAURANT, *Wayne State University, Department of Mathematics, Detroit, Michigan.*

Let X be the time-to-failure of a system. The model presented is the generalization of two models: the Teissier-Laurent and the Epstein-Sobel models. One assumes that the aging of the system is characterized by a law of exponential decay for the expected time-to-failure of the system at age x and that the system is also submitted to a constant rate of fatal accidents. Then the survival function is given, in reduced variable $t=X/E_0$ or $t=(X-X_0)/E_0$, by $S_1(t)=\exp.[1+mt-\exp(t)]$. This model is studied from the viewpoints of probability and statistical inference. Further generalizations are discussed with their *rationales*, namely the model $S_3(t) = S_1(t)S_2(t)$, where $S_2(t)$ is the incomplete gamma distribution, and the model obtained by replacing t by t^c.

WA5.5 Partitioning Electronic Equipment Through the Use of a Symptom-Matrix, GRAFTON GRISWOLD, *Senior Project Engineer, ARINC Research Corporation, 2551 Riva Road, Annapolis, Maryland 21401.*

This paper describes the application of a symptom-matrix* to the partitioning of an electronic equipment. The objective of the partitioning was to achieve a direct relationship between malfunction symptoms and the location of the causes of these symptoms. It was hypothesized that troubleshooting would be enhanced if an equipment is partitioned so that all the causes for each malfunction symptom are located in one or a few replaceable assemblies. Because it was not known if such a configuration could be accomplished within other system constraints, a feasibility study was established using the Indicator-Coupler Component of the AN/ARN-85 LORAN Receiver. A symptom-matrix was prepared for this component and then the component was repartitioned on the basis of the information contained in the matrix. A new matrix was then prepared for the reconfigured component and compared with the first matrix using information theory techniques.

* A symptom-matrix is a matrix of malfunction symptoms versus causes (part failures) the relative probability of occurence of each couple of symptom and cause noted at the intersections in the matrix.

It was found that the amount of information transferred from the knowledge of a symptom to the location of the cause was increased significantly (52%), thus reducing the number of errors that a maintenance technician likely would make in troubleshooting the reconfigured equipment. It was also noted that the number of interconnections between replaceable units was reduced which should result in increased equipment reliability and reduced manufacturing and test costs.

WA5.6 A Stochastic Model for the Optimal Replacement of a Deteriorating Component System, HARRY F. MARTZ, JR., and DAVID B. BROWN, *Texas Technological College, Lubbock, Texas.*

A modified Markovian inventory model is used in formulating a model for the optimal replacement policy in a system composed of N component parts. The components are allowed to deteriorate in a probabilistic manner and a total system efficiency is defined as a weighted function of the component deterioration. This overall efficiency may be interpreted as a gauge on the state of the system. The replacement policy is described by two non-negative critical values u and v. If at certain discrete time points the system efficiency is less than or equal to u we replace r items to bring the efficiency to a predetermined value v. If the efficiency is greater than u we make no replacements. A matrix return function utilizing interval arithmetic is defined which enables an optimal replacement policy to be formulated. Some simulated computerized examples of this procedure are given. Finally, the paper concludes with comments relative to extension of the procedure to a continuous time process and in particular a pure diffusion model.

WA5.7 Input-Output As An Aid To Military Decision Making, RICHARD JENNER and JOSEPH AUGUSTA, *Center for Naval Analyses.*

In common with all leaders of large and increasingly complex organizations, military planners must base rational decisions on accurate knowledge of all relevant costs for each of the alternatives from which they must choose. Cost figures that adhere to this simple and obvious concept, however, frequently are not easy to obtain. This difficulty is caused primarily by the specialization of function that occurs within a complex military organization. Specialization leads to interdependence. The great interdependence between the activities of constituent parts causes any change in one to affect one or more of the others in ways that are frequently extremely complex and difficult to foresee. For example, increasing the number of personnel in an infantry battalion would induce an increased demand for such personnel supporting services as medical facilities, military training, specialized training, and food services. Furthermore, it would induce new demands for maintenance and supply support for the increased quantity of equipment required, such as motor vehicle mechanics. Moreover, still further changes will be derived from the initial change. For example each new mechanic will receive many support services, including those already listed, from military units that are external to the infantry battalion. Each of these units, in turn, must increase its useage of all types of inputs that it needs. All such changes must be counted in the evaluation of the total cost of increasing the size of the infantry battalion. The authors have completed extensive research into the problem of

determining the total costs of alternatives within a large and structurally complex military establishment. They conclude that all conventional costing techniques, including the various systemic approaches usually called "cost models", are unable to provide more than a limited portion of all costs associated with any given choice because they contain significant structural deficiencies. The authors propose, instead, that only a model constructed from conventional input-output techniques is capable of capturing all costs, including all possible indirect or derived effects. The accuracy of cost data provided by such a model is limited only by the accuracy of the data put into it, and not by the structural characteristics of the model itself. The authors are currently preparing a paper in which the details of this research will be set forth. This paper will also include a survey of the more significant difficulties that are likely to be encountered in the construction of such a cost model. The central thesis of this research can be expressed as follows: Conventional costing techniques are basically designed to express the various elements that comprise a military system in terms of their monetary equivalent. By concentrating on monetary values, however, such techniques are not able to account for the flow of goods and services between these elements, since such internal flows are seldom priced. On the other hand, such "real" flows are the source of most structural interdependencies within a military organization. Therefore, structural relations must be superimposed on conventional costing techniques, almost always on an *ad hoc* basis. Input-output models, on the other hand, depict the resource flows that bind the various components of a system into an interdependent whole. For this reason they are well able to capture all cost changes within a complex highly interdependent military organization.

WA6.1 Equipment Utilization Analysis by Simulation, FROMAN HULBERT, *USAID ADPA, Management Advisor, to the Minister of Public Works, Republic of South Vietnam and Consultant to the Prime Minister's Committee for Administrative Improvement.*

This study proves the contention that the least cost equipment complement, under multi-server and multi-user conditions, depends, in part at least, upon the extent to which jobs are delayed or deferred where facilities are restricted. The paper describes the development of a utilization model and the results of simulating different equipment configurations with constant work loads. The model features a deterministic rather than Poissonian arrival system and develops a unique relationship between the arrival and service time parameters. The least cost complement is rigorously determined. The study further demonstrates that the simulation technique can result in a fairly precise and finely sculpted model of a "real world" situation. With careful analysis and a system as flexible and versatile as GPSS-III (IBM), maximum verisimilitude can be realized. The equipment items studied are high-value cartographic viewers located in the Aeronautical Chart and Information Center, U. S. Air Force, in Saint Louis, Missouri.

WA6.2 Combinatorial Analysis of JXM Sequencing Problems, SAID ASHOUR, *Department of Industrial Engineering, Kansas State University, Manhattan, Kansas 66502.*

The JXM sequencing problem discussed in this paper is that of determining the sequence in which J jobs are to be performed on M machines so that the schedule time is minimized. It is apparent upon considering the combinatorial nature of this problem that exclusive enumeration is impossible, even with the most powerful and fastest computers. Several combinatorial techniques were porposed in literature to curtail the number of the sequences. The efficiency of these techniques depends on how effectively enumeration is curtailed. The purpose of this paper is to: (1) review the promising combinatorial techniques; (2) develop explicit computational algorithms for some of these techniques; (3) illustrate these techniques by solving a sample problem; (4) point out the deficiencies which have been overlooked in these techniques; (5) proposed certain improvements to some of these techniques; and (6) evaluate these techniques in terms of the efficiencies of the solutions obtained and computation times spent.

WA6.3 Invariant Imbedding and Adaptive Forecasting, E. STANLEY LEE, *Department of Industrial Engineering, Kansas State University, Manhattan, Kansas.*

The concept of invariant imbedding has been shown to be an effective tool for obtaining the missing initial or missing final conditions of a boundary value problem. In this paper, this concept is applied to the problem of adaptive forecasting. First, the smoothing problem is formulated as a problem in the calculus of variations. An expression for the missing final condition is then obtained by invariant imbedding. This missing final condition is esssentially the desired forecast. The classical least squares criterion is used. Since only the missing final condition or the desired forecast is obtained, the forecasting scheme is a sequential one which is fairly simple to compute. The rate of response to the demand can also be adjusted easily by changing the value of the weighting function. The advantages and disadvantages of this approach are discussed.

WA6.4 Meta-Adaptive Modeling and Forecasting of the Series, AMBAR G. RAO, and ARTHUR SHAPIRO, *Operations Research Department, Mobil Oil Corporation, 150 E. 42nd Street, New York, N. Y. 10017.*

Adaptive forecasting schemes are usually based on a method that modifies the value of a certain parameter—for example the smoothing constant—in light of the latest data. No effort is made to change the *model* of the series. Also, the adaptive procedure itself is specified in advance, although simulation results show that certain adaptive procedures are most suitable for certain types of time series. This paper proposes two methods of adaptively modeling a non-stationary time series, possibly containing a cyclical component and a changing trend. One of the two methods is selected at each point in time in order to make forecasts. This selection procedure is itself adaptive—hence the title Meta-Adaptive Forecasting. The modeling methods are based on the use of evolutionary spectra. Previous papers at the 32nd and 33rd National ORSA meetings have demonstrated the usefulness of the spectral method in short range forecasting.

WP1.1 *Implementation of a Multi-Location Large Scale Computer Based Order Entry System, THEODORE D. ROBBINS, *Eastman Kodak Company, Distribution Center, Rochester, New York.*

During the past several years, Eastman Kodak has been engaged in the development of a new customer order entry and billing system. This system is in the process of being installed and in its final form will utilize a teleprocessing system to link IBM S/360 model 20 computer terminals in Kodak's Regional Distribution Centers to a large scale S/360 model 65 computer located in the Company's Central Distribution Center. The new system will lead to several major changes in Kodak's distribution operations and cuts across several major responsibility areas in the Company. This paper will review the general approach taken in organizing the effort necessary to design, develop and install this new system.

WP1.2 *Some Psychological Problems Involved In Implementing Change in Organizations, LANE RILAND, *Eastman Kodak Company, 343 State Street, Rochester, New York 14650.*

Traditionally, industrial and business organizations have stressed the financial, mechanical and rational aspects of systems to a greater degree than the human aspects in their planning for change. Organizational change often is accompanied by a resistance on the part of the human element in the system and the results are usually disfunctional for the manager, systems analyst and the organization itself. However, this resistance on the part of those "changed" is quite normal and predictable human behavior under certain circumstances for the individuals concerned. An analysis of current management theories and practices, and particularly their implied assumptions regarding human behavior provides insights into and explanations of many current (and future) problems, with regard to the effects of change on human beings in organizations. It is felt that among many of the practitioners of complex systems implementation today there is a lack of understanding (if not concern) of the effects of their efforts on the human beings involved both at managerial and lower levels. These resultant effects often determine the success or failure of an effective systems implementation. Organizational psychology provides possible methods of reducing resistance to change. Some ramifications of these methods with regard to the role of the change agent as well as management will be explored.

WP1.3 *Implementation in Operations Research and R and D: in Government and Business Organizations, MICHAEL RADNOR, ALBERT H. RUBENSTEIN, and DAVID A. TANSIK, *Northwestern University, Evanston, Illinois.*

Many of the organizational problems that are inherent in the integration of innovation-producing activities come to light in the form of difficulties experienced in achieving implementation of output. Such difficulties are common not only in operations research but in most forms of innovative activity, among them R and D. Growing out of the work that has been pursued at Northwestern in research programs on both the R and D process and the management of operations research/management science (OR/MS) activities, this paper examines the systemic causes of such implementation problems. We have further hypothesized that the en-

vironment in which innovative activity is carried on is an important determinant of the mode and effectiveness of project implementations. Specifically, we have considered how goal operationality differences, such as may be found between government and business organizations, will influence the strategic behavior of the managers of innovative groups. The data base for this paper comes from OR/MS and R and D studies in approximately one hundred business and fifty government organizations.

WP1.4 Implementation of a Large Scale Production Distribution Planning System, B. R. BUZBY, *Consultant, Management Services, Union Carbide Corporation,* and J. P. KELLY, *Manager of Information and Planning Systems, Distribution Department, Union Carbide Chemicals and Plastics.*

This paper will highlight the factors that affected the successful implementation of a planning system developed for a chemical complex which is multi-product, multi-plant production and distribution network. Plans computed on a monthly or quarterly basis are intended to answer such questions as: which manufacturing processes should be utilized and how should they be operated, what raw materials should be purchased and in what quantity, which plants should produce how much of what products, what distribution patterns should be used for stocking terminals and warehouses, what shipping locations should be used to satisfy customer orders, and what are the least cost alternatives when the optimum course of action is temporarily not available. The nature of the problem and need for a solution, the results achieved after one year of actual use, and anticipated future developments are described. The emphasis of the discussion is the abstraction of the key problems and principles that controlled the development and implementation process. Conclusions are drawn as to the most significant ingredients required for the success of a system of this nature as a commercial business activity.

WP2.1 *An Adaptive Control Model for Partitioning a Population between Two Treatments, Each of whose Effectiveness Changes with Time, JOHN D. C. LITTLE and JOEL SHWIMER, *Sloan School of Management, MIT, Cambridge, Mass. 02139.*

In a number of recurrent operations, for example the solicitation of a population by direct-mail promotion, it may be desirable to use a part of the population to try out new ideas for increasing response. In this model we hypothesize a choice of two treatments at each decision point. The effectiveness of each treatment changes with time. The problem is to partition the population between the treatments so as to maximize the long run expected gain. This involves a trade-off between immediate gain and information collection for later gain. The dynamic programming solution is compared with various simple heuristics in a numerical example.

WP2.2 *Some Adaptive Models for Sequentially Setting Advertising Budgets, PETER T. FITZROY, *Wharton School of Finance & Commerce, University of Pennsylvania, Philadelphia, Pa. 19104.*

We are concerned with the problem of determining the advertising budget

when the effectiveness changes over time as a result of economic, social and competitive factors. A number of decision rules are developed involving various combinations of estimation and control procedures. These decision rules are optimal, but in certain restricted senses. Finally, these decision rules are evaluated in a variety of simulated environments.

WP2.3 *A Model for Diagnosing and Correcting Problems in New Product Introduction, GLEN URBAN, *Sloan School of Management, MIT, Cambridge, Massachusetts.*

An adaptive model structure for locating and solving the problems that occur in new product introduction is presented. The model operates within an information system that monitors the micro-level behavioral processes in the diffusion of the new product innovation. These observed values are used to update the prior specifications of the models response parameters. The newly updated parameters are processed by the model to generate forecasts of sales, profit and market share. If these forecasts are not satisfactory, a new set of the "best" decision variables are found by an on-line iterative search routine directed at maximizing profit. An application of the model to a new frequently purchased consumer product is presented. On the basis of this first test, the model seems to be useful in problem finding and problem solving in new product introductions.

WP2.4 *NOMMAD: Adaptative Microsimulations of New Product Demand, JEROME D. HERNITER, *Michigan State University, Lansing, Michigan,* and VICTOR J. COOK, *Marketing Science Institute, Philadelphia, Pennsylvania.*

NOMMAD is designed to serve as a realistic demand model component of an adaptative marketing planning system. It is compatible with both designed experiments and updated market information concerning company marketing activities and consumer responses. The model uses a series of data inputs including pre-test marketing data, test market information, and ongoing market tracking data. The microsimulations in the NOMMAD series are being developed and tested in cooperation with several companies. This paper discusses one model in the NOMMAD series.

WP3.2 *The Impact of Information Transfer Satellites on Every-Day Living, GEORGE E. FOSDICK, *Technical Staff, Systems Analysis Dept., Martin Marietta Corporation, Denver, Colorado 80201.* GEORGE W. MORGENTHALER, *Director, Research and Development, Martin Marietta Corporation, Denver, Colorado 80201.*

We are in the midst of an information explosion. It is becoming increasingly more difficult to be aware of—let alone absorb—the staggering amount of information available. One aid in the control and dissemination of information is a proposed multifunctional information transfer satellite network. Potential mission applications include postal services, navigation and traffic control, Earth resources monitoring, voice and TV broadcast, library services, value transfer (automated credit transfer), reservation services, and many more. Alternative systems are described for these missions with specific applications to library services, value

transfer and TV broadcast. A mission scenario is provided for each which includes an overall description, a user profile, description of services provided, the user console requirements, and the transmission media. System design alternatives affect both cost and quality of service. Technological trade-offs exist between relatively simple spacecraft and relatively complex ground equipment and vice versa. In addition, the system network itself can be designed to utilize telephone lines, microwave, trans-Atlantic cable, etc., in various combinations. Scheduling of services of the store-and-forward type to off-peak hours allows the real-time load to be serviced better. The method of approach is described and both system costs and costs to the user are presented as functions of mission combinations, network design, and quality and speed of service provided.

WP3.3 *Linear Programming Solutions for Orbital Transfer Trajectories, CHARLES M. WAESPY.

This paper describes how the relatively efficient computational techniques of Linear Programming can be used to obtain near minimum fuel solutions to the problem of controlling spacecraft midcourse, and terminal control trajectories. These "orbital transfer" maneuvers are required (a) to bring a spacecraft to a prespecified position; velocity and time state so that its subsequent free-fall trajectory follows a desired path, or (b) to match the position and velocity of another orbiting spacecraft in order to achieve a rendezvous or station-keeping condition. Modern optimal control theory has provided means by which the necessary (and in some cases, sufficient) conditions for the optimal control function for this problem can be derived. However, each method leads to subsidiary computational requirements which have proved troublesome in engineering practice. In view of the computational demands of optimal control theory, it appears worthwhile to study how the computational power of Linear Programming can be brought to bear. This paper applies Linear Programming methods to the terminal guidance of an orbiting spacecraft. Typical trajectories based on linearized (the so-called Wiltshire-Clohessey) equations of motion are calculated. Under the assumptions made, these minimize fuel consumption. The capabilities and limitations of Linear Programming in this application are described. In the formulation used in this paper, an analogy between the minimum fuel problem of optimal control theory, and the allocation of resources problem in the economic theory of the firm is readily apparent and will be described. Attention will also be called to current research which is beginning to provide a more profound interconnection between optimal control theory, and the mathematical programming techniques familiar to operations research and management science. This trend, and its characteristics will also be described in the context of the orbital transfer problem.

WP3.4 *Outage and Replacement Implications for Operational Satellite Systems, R. A. DAVIS, *Director, Systems Evaluation Office, Aerospace Corporation.*

In establishing design requirements for an operational satellite system, the user has the double problem of deciding on a suitable outage criterion and finding the cheapest way to meet it. Toward that end the paper discusses typical trade-

offs between system outage and the number of satellites needed during the system's operational lifetime. It assumes a policy of replace-as-fail for various mean times before failure, mean replacement times, and numbers of active or dormant spares in orbit. The results show that, for outages as low as some missions may require, the system can cost significantly more than might otherwise be calculated. Ways of minimizing these effects are touched on.

WP3.5 *Mathematical Models for Space Station Program Planning, L. J. YORK, *Operations Research Section, Fort Worth Division of General Dynamics, Fort Worth, Texas.*

This paper presents the general formulation, structure, and applications of a set of computer programs which have been developed for use in mission analyses and program planning across a spectrum of space station concepts. The input for these programs consists of a mission profile, an experimental program to be accomplished, and a description of the space station and logistics carrier capabilities. The individual computer models are then applied in sequence to generate detailed mission schedules, and to provide a set of evaluation parameters reflecting cost and resource utilization rates of these schedules. Primary emphasis is placed upon (1) determination of crew skill requirements, (2) optimal assignment of experiments to crewmen, (3) determination of expendable utilization requirements, (4) development of logistics profiles, (5) development of crew activity profiles, (6) development of experiment execution schedules, and (7) simulation of the occurrence and assessment of the impact of random phenomena such as system failures, repair times, and crew illnesses. Case problems and their solutions are presented which demonstrate the utility and flexibility of the models in analyzing a broad array of situations resulting from variations in combinations of experiment programs, space station concepts, astronaut training programs and logistics systems.

WP4.1 *Simple Models Useful in Allocating Aerial Interdiction Effort, CLAYTON J. THOMAS, *Operations Analysis, HQ USAF, Washington, D.C.*

In allocating interdiction effort—tactical fighter sorties—an air force has a great many options. It may attack a variety of targets—vehicles, routes, stockpiles, components of an enemy defense net—at different times of day in several geographical areas. Similarly, the opponent, in trying to structure a viable and effective transportation system, has many options in his choice of mode of transport, route, time of day and weather condition, allocation of defenses, etc. While no single model is likely to capture all of this complexity in a useful way, several simple mathematical models have helped to estimate the results of changes in allocation of effort or to bound the optimum results that the opponents can attain under various constraints. Following a discussion of measures of effectiveness, several simple models are described. These include one-sided and two-sided optimization models. Among the former is the problem of minimizing the transport flow that emerges from an area subject to air attack, subject to a constraint on available sorties and a constraint on tolerable losses of aircraft. Examples show the sensitivity of results to the character of G. Elementary ways of relating such simple models to more complicated network models are also described.

WP4.2 *A Dynamic-Programming Approach to Populace Screening in Counterinsurgency Operations, GLENN F. LINDSAY, and ROBERT L. VOGT, *Department of Operations Analysis, Naval Postgraduate School, Monterey, California.*

Under current practice an important part of counterinsurgency operations deals with the screening of the populace through search and interrogation, so as to apprehend insurgents and their supporters and thus reduce or control the pro-insurgent proportion of the population. In planning these operations for a given area, decisions must be made concerning the frequency with which screening efforts will be undertaken, the force size to be used, and the length of time the force will operate in the area during each visit. The problem is viewed as one of sequential decision making, and recursive relationships are developed describing insurgent growth when screening forces are not in the area and the decrease in the proportion pro-insurgent as a consequence of the screening activities. For cost criteria including setup and unit screening costs, costs for man-days of insurgent presence in the area, and the cost of insurgents remaining at the end of the planning period, it is shown that the minimum-cost search and screening plan will be extreme-point so that when screening is undertaken, the search force should be the largest available. A dynamic-programming algorithm is proposed for determining the minimum-cost frequency and durations of search and screening activity.

WP4.3 *Fighter Aircraft Performance Modeling, Simulation, and Flight Testing for Research and Development, TERRELL E. GREENE, and R. L. SPICER, *The RAND Corporation.*

Among the techniques available for investigating in detail the performance of real or hypothetical aircraft are a spectrum of simulation techniques ranging from pure computer modeling, on the one hand, to flight tests simulating combat operations, on the other. Intermediate between these techniques, in several senses, is simulation involving one or more pilots on line with a computer and display system, "flying" simulated aircraft in real time. Although all three classes of technique involve varying degrees of simulation, for ease of expression they are referred to here as modeling, simulation, and flight testing. Each of these classes of technique contains a number of examples of varying complexity. Each class has its typical advantages and limitations and is most appropriate for certain types of investigation. A comparison among them is made on the basis characteristics such as the following: degree of experimental control, ease of variation of parameters, range of parameter variability, cost per case, time required per case, realism and credibility. The suitability of the three classes of technique is considered primarily in terms of their value for design studies and design evaluations, but references are made to other uses such as training and development of tactics. It is suggested that the more complex forms of these techniques are particularly significant for fighter aircraft, as compared with other aircraft types, for two reasons. One is that the high performance standards to which fighters are designed makes them capable of maneuvers that cannot be investigated adequately with simple models, simulations, or flight tests. The other is that in some cases it is

extremely difficult to express fully, in quantitative terms, the relations between a fighter's aerodynamic performance and its performance of combat tasks. In these cases the techniques referred to here can provide empirical observations of performance of combat tasks as affected by changes in aircraft design factors.

WP4.4 *The Roles of Nike-X: An Integrated Weapons Systems Programming Model, RONALD L. ARMS, JEROME BRACKEN,* LAURENCE A. LYONS, JOSEPH V. MICHALOWICZ, FREDERIC A. MIERCORT, NICHOLAS M. SMITH, and PETER C. TOSINI, *Research Analysis Corporation, McLean, Virginia.*

A set of weapons systems models in the form of a moderately large-scaled nonlinear piecewise continuous constrained programming model whose constraints are themselves suboptimizations has been developed and placed in operational status. The basic model minimizes the time-phased cost to BLUE needed to maintain a military posture with respect to a surprise attack initiated by RED. BLUE economic resources are allocated to determine the mix of offense-defense weapons systems against a fixed schedule of RED weapons assuming he follows a suboptimal tactic with respect to various BLUE design strategies of "assured destruction," "damage limiting" and "parity." Other models commute the RED-BLUE postures and options with respect to first strike. The models implicitly determine the marginal values of civilian and economic sectors with respect to military. A combination of models are utilizable on an iterative basis to optimize the costs to both RED and BLUE starting from initial postures and with respect to particular national strategies not necessarily zero-sum. The model is flexible with respect to a wide variety of inputs and may be used to place the results of any component study in consistence with studies in other sectors. Among the applications discussed will be a study of arms stability. Sample calculations using public or hypothetical data will be used to illustrate the versatility of the models.

WP5.1 *Systems Analysis in Four Cities, HAROLD R. MILLIE and W. EDWARD CUSHEN, *Technical Analysis Division, National Bureau of Standards, Washington, D.C.*

Four systems analysis projects conducted by the staffs of those cities, reported as under way at the TIMS/ORSA meeting in San Francisco, have now been completed. These studies involved: (1) planning for fire station location and fire services in East Lansing, Michigan, (2) selecting strategies for achieving building code compliance in Poughkeepsie, New York, (3) the location of a serivce facility in Charlotte, North Carolina, and (4) a capital budgeting problem in Fort Worth, Texas. Lessons learned about the conduct of city studies will be presented. An early critique of the use of study results will be made. Specific numerical answers to the projects and policy issues affected will be given.

WP5.2 *Time Sharing Use of Computers in Large Urban Governments, NACHMAN BENCH, *Special Studies, Inc., New York, New York.*

Many large cities have successfully applied EDP to traditional clerical opera-

* Now at IDA.

tions in several separate areas, with each area having its own computer and files. Substantial benefits can be obtained through the concept of sharing—of information, files, time, and processing. This concept can be implemented through the following steps. 1. Development of real-time inquiry systems in city departments and agencies. 2. Development of data banks for sharing basic information. 3. Consolidation of computer systems into one or two large data centers, with several smaller centers, to reduce the cost of processing, to integrate information systems, and to consolidate common files.

WP5.3 *Gaming-Simulation of Urban Decisions—The M.E.T.R.O. Project, RICHARD DUKE, *School of Natural Resources, University of Michigan, Ann Arbor, Michigan.*

The M.E.T.R.O. Project utilizes operational gaming techniques to develop a plan implementation instrument. This has the capacity of demonstrating to appropriate decision-makers the consequences of alternative decision chains on metropolitan growth patterns. This is accomplished through the use of a simulated, abstracted environment, employing a reduction of time span and dynamic interplay of current decisions with fixed policies. The instrument is intended to simulate growth patterns which would occur naturally and enable their comparison with planned growth patterns. In addition, M.E.T.R.O. is designed to: (1) illustrate the kinds of information which are available to decision-makers (e.g., data banks), (2) inform the decision-makers about the techniques which are available to evaluate and implement decisions (e.g., mathematical growth models and capital improvement programs), and (3) provide information concerning the implications for urban development which are associated with alternative courses of action. It simulates a community in which players assume key roles and relationships, becoming involved simultaneously in public and private decisions which influence the game. Both the dynamics of policy formation and the consequences of individual decisions become explicit in the course of play.

WP6. Panel on Information Retrieval Session, *Chairman:* MARY HAWES, *Information Systems Leasing Corporation, Philadelphia, Pa.*

The Information Retrieval session will attempt to combine in one afternoon both a tutorial type introduction to information retrieval and a discussion of how a data base system with comprehensive information retrieval capability is used in a management information system environment. The session will end with a brief discussion on problems directly associated with information retrieval that users will encounter. The speakers have each participated in the development and use of information retrieval systems. John Young of NCR will give a brief historical development of both document retrieval and information retrieval systems demonstrating how they differ and where each is used. He will also discuss briefly retrieval systems that are available today or which will soon become available. John will bring out the advantages of a user operating from a console and making use of data stored in a data base. Mary Hawes of Information Systems Leasing Corporation will present some of the practical problems associated with Information Retrieval many of which are associated with the creation of the

data base and knowing what data is available. The indexing textual material, the development of data dictionaries, obtaining and classifying data in support of ill defined problem areas, the limitations of Boolean logic for retrieval are problems that are still with us. Another problem facing the developers of information retrieval systems is associated with knowing how operation research type people would like to ask for the data they need.

WP7.1 *Combinatorial Programming, GLEN GRAVES, *Graduate School of Business, University of California, Los Angeles, California* and ANDREW WHINSTON, *Herman C. Krannert Graduate School of Industrial Administration, Purdue University, Lafayette, Indiana.*

The paper will first present a rigorous mathematical basis for the aspect of combinatorial programming developed by the authors. Several current applications of the basic ideas will be surveyed. Finally the possible application to continuous mathematical programming will be considered.

WP7.2 *Some Polyhedra Related to Combinatorial Problems, RALPH E. GOMORY, *Thomas J. Watson Research Center, IBM, Yorktown Heights, New York.*

The asymptotic theory of integer programming can be shown to reduce to the study of a certain class of polyhedra whose vertices solve the asymptotic problem and whose faces give new inequalities for cutting plane methods. Properties of these polyhedra and their connection to integer programming will be discussed.

WP7.3 *Duality in Discrete Programming: IV Applications, EGON BALAS, *Carnegie-Mellon University, Pittsburgh, Pennsylvania.*

In three earlier papers, a duality theory was proposed for discrete linear programming (I) and extended to discrete quadratic programming (II), as well as to other cases of discrete nonlinear programming with nonlinear constraints (III). In this paper algorithms will be discussed which use some of the above results.

WP7.4 *Faces of an Integer Polyhedron for Cyclic Groups—Part II, FRED GLOVER, *University of Texas, Austin, Texas.*

Faces of a certain integer polyhedron identified by Ralph Gomory provide strong cuts for integer programming. In an earlier paper, "Faces of an Integer Polyhedron for Cyclic Groups—Part I" the author gave a method for generating a large number of these faces very rapidly for cyclic groups under the assumption that the group order and the number of variables are equal. Procedures are given here that directly generate large numbers of faces when the number of variables and the group order may not be equal. In addition, special procedures are given for generating a select number of "good" faces.

WP7.5 *Sentential Programming, GERALD L. THOMPSON, *Carnegie-Mellon University, Pittsburgh, Pennsylvania.*

In many applications, problems require programming formulations in which there are two kinds of variables, (a) those connected with observed quantities; (b) those introduced for the purpose of stating logical relationships. Variables of the second class are frequently, but not invariably zero one, and usually result in large increases in tableau size. Sentential programming gives a way of handling variables of type (b) within the simplex code, and without increased tableau size. It can be regarded as linear programming over a non-convex set of constraints. The present paper discusses the theoretical basis of sentential programming including duality theory, and also gives limited computational results.

WP7.6 *Turnpike Theorems for Integer Programming Problems, JEREMY F. SHAPIRO, *Massachusetts Institute of Technology, Cambridge, Mass.*

The structure of integer programming problems is investigated by means of a dynamic programming formulation. A group theoretic result of Gomory is then given the following interpretation. Consider the class of integer programming problems with a variable right hand side resource vector b but with fixed activities and cost coefficients. There exists an integer m-vector b^* such that for all integer m-vectors b satisfying $B^{-1}b \geq B^{-1}b^*$, where B is an optimal linear programming basis, the optimal immediate decision when given resources b is to use any one of the optimal basic activities once, and proceed optimally thereafter. Integer programming problems which satisfy this property are called steady-state. The result is extended to all integer programming problems. In effect, the extension identifies the steady-state and transient components of a given integer programming problem.

TA1.1 *Organization for Maintaining Individuality in a Team Situation in R & D, E. C. HUGHES, *The Standard Oil Company (Ohio), Cleveland, Ohio.*

The creation and preservation of the spirit of professional individualism among scientists and engineers is one of the most important jobs of business management. These people are hired for their personal abilities; therefore a company should manage them so that they feel a pressure to remain professional. The factors which lead to maintaining individuality are considered both from a human standpoint and from the control and accounting for research. Having established something of the necessary managerial atmosphere for maintaining the values of personal professionalism, management must then consider how to team these individuals for the necessarily large problems of industry. Obviously the first criterion is that the method of teaming will not destroy the efforts to maintain individualism. Three of the teaming devices are discussed, namely, (1) the formal chart organization, utilizing participative-consultive techniques of management rather than authoritative, (2) the task force, and (3) formulation of dotted line relationships which we call "mini-system." These tools of organization are usually

used simultaneously. Each of these is described in relation to a real-life R&D organizational philosophy. Each has its own system of playback to the individual within it, which starts with the evaluations made by management. Thus, a consideration will be given to the accounting system for describing the productivity of R&D units. Obviously, simple dollar numbers fail to do this within the motivation time span required for the individual professional. Other means of doing this are described with particular emphasis on the development of supported opinion at managerial level.

TA1.2 *A Mathematical Basis for the Selection of Research Projects, ARTHUR H. BOBIS, *American Cyanamid Company, Bound Brook, New Jersey.*

During the past few years many articles have appeared describing mathematical models intended for use in evaluating research projects. These can be broadly separated into two categories: simple models which treat the process of research as if it were static and complex models which deal with research as a dynamic problem. In reviewing this literature, Baker and Pound state that the simple models ignore what is perhaps the essential aspect of the problem and are, therefore, of questionable utility, while the more complicated models require so much information that their usefulness can never truly be tested. With this paper, we are adding to the proliferation of methods and models. But we believe we have chosen a course which avoids the previous inadequacies and which, while dealing with the real problem, treats it in such a way as to encourage use of the method. The justification for our belief is that the model has been developed in consultation with groups of researchers and that management find the results helpful in evaluating and planning research efforts. Our point of departure for this work was the paper of Hess. In building a mathematical model of the research process, we have had to make use of estimates of such quantities as the probability that a project will succeed. Although these is no means of checking such a number and also no frequentist interpretation of such probabilities, we have handled subjective probabilities as though they described recurring events. Also, no attention has been given to problems arising from optimistic or pessimistic estimations of such quantities as sales. We have worked on the assumption that decisions have to be made, usually on inadequate data and that they will be made intuitively on the data whatever its quality. Anything that can be done to quantify the bases for these decisions and to demonstrate the logical consequences of the assumptions is a step in the right direction. The paper covers the use of estimates of the cost of the project to develop a probability model, structuring the commercial information for use, and the rate of research expenditure. Simulation techniques are discussed, and a budget is selected on the basis of maximizing the return.

TA1.3 *Selection and Planning of Research and Development Projects, J. F. MCCARTHY, JR. and R. L. STROM, *Space Division of North American Rockwell Corporation, Downey, California.*

Aerospace companies face a challenging problem in allocating independent Research and Development (IR & D) funds and other company resources. A

company must evaluate future needs and requirements, and select areas in which it wishes to compete. R & D projects must be identified which can develop the capabilities which will contribute to increasing the probability of success in these areas. Criteria must be established for selection between the large number of projects which are usually available for this purpose. Standards are also required, against which performance may be evaluated and controlled. This paper outlines a system which provides a logical basis for selection and planning of R & D projects. A procedure for establishing an integrated hierarchy of objectives is described. The following information is required as a part of each project proposal: (1) its contribution to fulfillment of one or more objectives, (2) a cost-benefit analysis, (3) the requirements for success, (4) elvauation of existing capabilities, (5) deficiencies which must be remedied, (6) milestone events and dates, and (7) estimates of incremental and total costs. Often, the first increment of work should be concentrated upon gaining knowledge which can reduce the uncertainty of estimates of the probability of success of the venture, rather than routine problem-solving steps. This makes it possible, during periodical review of R & D projects, to determine whether the additional information which has been obtained recommends continuance or termination of the project. Resource allocation is based on estimates of the potential value of each candidate R & D project. Criteria for the resource allocation decision include risk, incremental investment, total investment, breakeven point, and probability of success. The system employs control by exception based upon deviation from predicted standards of performance and specific line items in the R & D plan.

TA1.4 *Experiences in Developing and Using A Planning and Control System in R & D Management, WILLIAM E. SOUDER, *Monsanto Company, St. Louis, Missouri.*

Several years ago the management of the Organic Research Department of Monsanto decided that the successful selection, budgeting, and monitoring of future R & D projects would require more sophisticated approaches than had been used in the past. In addition, there was a need for a more rigorous decision-making framework that would help develop consistency in value judgments among various managers, better integrate relevant information inputs, provide a laboratory for decisionmaking and substitute "organizational consensus' for "organizational oligopoly" in the practice of allocating funds among competing groups. Based on a survey of existing practices in the department and a stipulation by management of the desired practices, a theoretical planning model and a theoretical control model were developed. The planning model views R & D project selection, resource allocation, and budget determination as interrelated components in a production economics problem that is constrained by manpower limitations and certain behavioral parameters. A two-dimensional dynamic programming algorithm is employed parametrically and heuristically to help management select satisfactory R & D policies. The control model relates project cost and achievement and develops variances between actual and predicted costs and achievements over time. These variances provide early warnings of impending project failures, conceptual analyses of the causes of these pending failures, and a de-

tailed analysis of the cost-effectiveness per dollar spent. The two models form an integrated, closed loop planning and control system. Pilot studies and field studies with the system have indicated that it is a highly effective aid for R & D managers, and full scale implementation of the integrated system is presently under way.

TA2.1* Some Marketing Applications of Nonmetric Scaling Techniques, PAUL E. GREEN, *Professor of Marketing, University of Pennsylvania, Wharton School of Finance & Commerce.*

The use of nonmetric scaling in the analysis of consumer behavior is still at an early stage of development and testing. This presentation discusses what has been learned in the course of using nonmetric methodology in some fifteen pilot applications dealing with the marketing of consumer and industrial goods. Current problems involve the interpretation of multidimensional scaling solutions and their dependence upon stimulus and environmental context. Implications for future research—conceptual and applied—are discussed as they relate to the problem of interpreting the empirical results obtained from these techniques.

TA2.2 *On Stability and Scenario Dependency of Perceptual and Preference Maps, PATRICK J. ROBINSON, *Marketing Science Institute, Philadelphia, Pa.*, and YORAM WIND, *Wharton School of Finance & Commerce, University of Pennsylvania, Philadelphia, Pa.*

The managerial utility of perception and preference mapping depends to a large extent on the stability of these maps. This stability is commonly assumed in most of the current applications of MAPP (Mathematical Analysis of Perception and Preference) to the analysis of marketing behavior. Yet, the validity of this assumption has rarely been examined. It is the attempt of this paper to present the results of some pilot studies aimed at the exploration of this issue—the sensitivity of perception and preference maps to changes over time and to the scenario used.

TA2.3 *A General Method for Preference Mapping of Perceptual Space, J. DOUGLAS CARROLL, *Bell Telephone Laboratories, Murray Hill, New Jersey.*

Given a multidimensional scaling solution yielding a representation of a set of objects in a "space" of small dimension, this method, developed by Carroll and Chang finds "ideal points" (in the sense of Coombs' "unfolding model") or "preferred regions" in this space based on preference data for each of a number of individuals. One may also solve for differential weights, or "saliences", of dimensions, or even for differential rotations of axes as well as weights. The rationale of the various models, and their geometrical, algebraic and statistical properties, are discussed. The practical value of the procedure is illustrated with real data.

TA3.1 *Multi-Dimensional and Dynamic Models of Organization and Personnel Placement, A. CHARNES, *Northwestern University*, W. W. COOPER, *Carnegie-Mellon University*, and A. STEDRY, *University of Texas.*

Problems of organization design and personnel assignment are assessed in

terms of a variety of vector optimizations. These models range from goal programming through game theoretic varieties and involve dynamic as well as static consideration of the effects of various assignments on the participants in the organization, the kinds of tasks that can be essayed and the opportunities for new designs (and assignments) that can be effected in passing from one environmental state to another. *Inter alia*, extensions of *present* procedures for personnel selection are also considered. In particular the methods which are explored for these purposes are not restricted to *individual* selections based on tests directed to *prearranged* jobs. The indicated extensions, in fact include consideration of possible selection and assignment *mixes* of persons simultaneously with rearrangements of job elements for alternate mixes of jobs which either (a) will produce more efficient task accomplishments or (b) obtain closer matches between jobs and persons. These kinds of approaches are assessed for their possible value in dealing with some of the present range of social problems (e.g., ghetto employment) as well as for their possible other advantages over presently employed methods of personnel selection, organization design, etc.

TA3.2 *Organizational Response to Change, JAMES A. VAUGHAN, *School of Business Administration, University of Rochester, Rochester, New York.*

This paper focuses on the behavioral aspects of the organization's reaction to and management of change. Specific attention will be given changes arising from internal as well as external causes in the organization's information system.

TA3.3 *Effect of Shift to Multiple Goals on the Model of a Public Agency, IRWIN P. HALPERN, *NASA, Washington, D.C.*

When a public agency with a small number of major goals, confined to a narrow area of the public sector expands its target to encompass a large number of goals spread over a very diverse area of public problems, there is a major shift in the agency's planning strategy, and in the model which it constructs in order to maximize its performance. This paper considers the ways in which such an agency must change its organization and goals in order to be responsive to a new set of constraints and resource implications.

TA3.4 *The Effect of Market Diversification on Private Corporate Strategy, JOHN J. HENRY, *North American Rockwell Corporation, Pittsburgh, Pennsylvania.*

The present governmental emphasis on turning to private industry for solution to high-technology problems in the public sector is involving corporations in tasks where consideration of public goals and social needs is demanding increasing attention from corporate planners. This paper examines the effect on corporate strategy of expanding the corporation's market from consumer products and governmental end-product contract items to include major governmental technological projects designed to meet pressing social problems.

TA4.1 *Mathematical Programming for Space Oriented Systems, GLEN SELF, *Texas A & M University, College Station, Texas.*

A certain class of Optimization problems have received renewed attention since space exploration has become a reality. These new applications result from optimum requirements for trajectory, burn rate, weight, volume, reliability and other similar restraints. As the duration of space missions become longer and the reality of logistical support becomes an operational requirement, the testing of previously academic optimization procedures will be conducted. The application of mathematical programming techniques to space mission planning has received wide spread attention in the operations research literature during recent years. Among those techniques which have been demonstrated as applicable to space planning have been the maximum principle, dynamic programming, geometric programming, the delta method, some integer programming algorithms, nonlinear programming algorithms, and even linear programming. More specifically, these algorithms have been applied in the area of availability, maintainability and reliability. There have been a number of discussions relative to the applicability of each technique. It will be the purpose of this tutorial paper to provide a survey or overview of the strengths and weaknesses of these competing techniques from the standpoint of the realities associated with space missions. This will include the consideration from the computational standpoint, the accuracy, and the protection against extremes which might be encountered in the actual space environment. In general, it is anticipated that this paper will provide a common base of reference for other participants on the program and may be used to precipitate comparisons and discussions relative to the other papers presented in the methodologies applied to space sciences. Examples will be provided in each of the mathematical programming techniques discussed and will be presented as discussion permits.

TA4.2 *Optimum Packaging Design and Sparing Levels for Extended Manned Space Missions, DONALD E. WAGNER, *NASA/MSC.*

This paper investigates the problem of optimizing the design of manned spacecraft systems with respect to the modular level at which on-board replacement of failed modules should be carried out. Failed items are assumed to be nonrepairable. The optimum design is considered to be the minimum weight (cost) for which a required reliability can be attained. A specific set of design alternatives in the form of a hierarchy of candidate replacement modules is used as the framework from which an optimum design is determined. A solution is obtained by a specialized version of a branch-and-bound integer programming algorithm. Some assumptions made are that there is no degradation of the reliability of spares and the time to failure of each component follows a negative exponential probability law. Provision is made for considering any number of common components for each replacement module. It is assumed that each of the penalties for sparing a given module, such as fault isolation and replacement times, can be expressed in terms of a common parameter. An example problem is presented and used as a basis for discussion.

TA4.3 *Space Station Experiments Program Analysis and Synthesis Routine, J. L. HOWSE, and T. E. PEACE, *Operations Research, Fort Worth Division of General Dynamics, Fort Worth, Texas.*

The structure and some applications of the Experiment Analysis and Synthesis Routine are described in this paper. The Routine, two computer programs written in FORTRAN IV for the IBM System 360 computer, is used (1) to perform a statistical analysis of the various resource requirements imposed upon an earth-orbital space station by a program of scientific experimentation and (2) to generate descriptions of various types of synthetic experiment packages suitable for use in the evaluation of the accommodation characteristics of earth-orbital space station concepts. The Experiment Package Analyzer classifies the experiments according to scientific field, develops frequency distributions for the appropriate experiment descriptors, and calculates the gross parameters of the input package. The Experiment Synthesizer Program, by drawing from these distributions, generates synthetic experiment packages to be used in conjunction with the Space Station Mission Simulation Mathematical Model (SSM) to analyze the abilities of various space stations to accommodate variations in experimental programs. The applications of these two programs are illustrated in a sensitivity analysis in which the SSM is used. Also presented are the variations of the resource utilization efficiencies and the measures of mission accomplishment resulting from mission simulations using these packages as inputs.

TA4.4 Methodology for Space Station Logistics Transportation Systems Analysis, Robert G. Voss, *NASA/HQ/OMSF*, and Carey H. Rutland, *NASA/MSFC.*

This paper deals with three general approaches to the problem of analyzing system requirements for space station logistics (crew menning and rotation, expendable resupply, and experiment module lofting). The general approach used is that of modeling the particular space station program such that the requirements may be determined directly from the model and the techniques for analysis are then structured so as to analyze the decisions relevant to the logistic requirements of those space stations. The considerations that are contained within the analysis include the number and crew size of stations and their location as to orbital altitude and inclination, the logistic spacecraft crew module size and the periodic rotation cycles which are involved, the medical experiments which must be reflected in the specific rotation cycle of selected individuals, the determination of the resupply of experiments and experiment modules as well as resupply of expendables for the manned station, and cargo capability and propulsive requirements of the spacecraft. Some of the hardware considerations involved are the operational mode of the logistics spacecraft while in orbit as to whether it is passive or active in the operations of the space station and its orbital staytime capability; manned versus unmanned supply vehicles; the utilization of propulsion modules in conjunction with the spacecraft for rendezvous with the space station; and the determination of the components of the basic load that is placed in orbit. The launch vehicles that are considered in the analysis include the present national stable as well as conceptual launch vehicles. The relationship to the total NASA effort is reflected in the consideration of certain interfaces between the space station effort and other parts of the space program. Three generalized techniques or developments in methodology used for the analysis are presented. The simplest approach is basically a graphical analysis of the various requirements of

space station logistics using a basic time line approach and a systematic evaluation of the requirements versus the logistic system alternatives. The second analysis technique presented is a form of matrix analysis which utilizes a regret type analysis of the requirements and the associated logistic system utilized to meet those requirements. The third technique which is applied to the analysis of this area is a basic perturbation of the importance factors to develop an overall sensitivity analysis of the plans for resupply relative to the general model requirements of the total space station complex. The logical development of the associated quantitative techniques for this analysis are presented throughout the paper. Characteristic type results for postulated programs will be presented.

TA4.5 *Techniques for Estimating Program Completion Cost, AUBIN O. FERGUSON, *NASA/MSC.*

There are a relatively small number of data points that are useful in establishing cost estimation in the space program. Due to this limitation in data both as to quantity and quality, it was necessary to develop some methodologies for utilizing as much of the available data as possible and still maintain some degree of engineering judgment and statistical validity in terms of the answers that might be provided. The particular techniques reported in this paper are those which develop the concepts surrounding the percent time percent cost curve as applicable to spacecraft subsystems and the methodology associated with the utilization of those curves for previously developed systems in determining the research and development cost pattern for either similar or new subsystems. The basic concept behind this approach is one of repeating patterns in research and development efforts being experienced for development of state-of-the-art systems, advanced systems or conventional systems. Even though the technique does not question the significant differences between competing case histories, it does utilize a concept of best fit when comparing partially complete programs with historical records on the cost expenditure versus time to completion. The paper explains the algorithm used for determining the best fit and for projecting those cost to completion of the project. Some examples of the utilization of this technique at various points during the history of a particular subsystem development program will be used to indicate the accuracy in convergence of the technique presented. In addition, some suggestions as to the similar problems which exist in this area and potential for consideration of the theoretical aspects as opposed to the empirical data collecting approach are presented.

TA-5 Panel on The Diverse Views of the Role of Cost/Effectiveness Analysis in Weapons and Force Selection. *Chairman:* MARTIN D. SCHWARTZ, *Autonetics, a Division of North American Rockwell Corporation, 3370 Miraloma Avenue, Anaheim, California 92803.*

For some time, and with recent crescendo, the application and/or misapplication of C/E analysis as an aid to decision has been debated widely. The panelists, all skilled practitioners, will discuss some of the important current questions: Does a C/E analysis background to decision differ anatomically from the so-called judgment of the generalist? How does C/E analysis influence the availability to

our Armed Forces of technologically superior weapon systems? Do the quantifiable aspects of weapons and force choices predominate over the unquantifiable aspects? What material result can be deduced concerning the quality and utility of weapon systems chosen for emphasis during the period of increasing reliance on C/E analysis as an aid to selection?

TA6.1 *Human Resources Development, BILLY BROWN, *Bureau of Employment Security*, JEREMY LIFSEY, *AUERBACH*, and DAVID MILLER, *AUERBACH*.

A pilot program for Human Resources Development was started in late 1965 in five cities, Chicago, Houston, Los Angeles, Rochester and St. Louis. The purpose of the program was to assist people who were not in the labor force or who had unusual problems that kept them from maintaining steady employment. Each HRD center was guided by USES Bulletin 2092 which defined the purpose, the population, functions and methodology for the HRD Program. The Bureau of Employment Security awarded a study contract to develop an evaluation instrument that could be used to provide information about the successful and weak parts of the program to aid in establishing effective HRD Centers throughout the United States. This paper describes the methodology, the results of this study, and work done subsequently by the Bureau of Employment Security to test the validity of the evaluation method. The approach taken during the study was to visit the various cities, observe the differences and similarities between the centers, develop an evaluation model, define the meaning of effectiveness, determine criteria and test the methodology of five sister cities. The methodology requires that a random sample of applicants be obtained, that a measure of the applicants' characteristics be recorded at time of entry and exit from the program, and that follow-up with employers, training personnel, counselors and the applicants themselves be used to verify the information obtained from official records. The evaluation instrument has been tested by the Bureau of Employment Security in on-going HRD Programs in several other cities. The reactions of Employment Security personnel are also presented herein.

TA6.2 *An Equitable Method for Allocation of Youth to Achieve National Objectives, BERNARD S. ALBERT, *General Electric Company, Missile and Space Division, Post Office Box 8555, Philadelphia, Pennsylvania 19101.*

The "draft," this paper concludes, has been a continuing problem because it has not been subjected to comprehensive systems analysis. The individuals and committees that have evolved solutions seem to have examined only a few aspects of a very complex problem; consequently, solutions have been controversial, partial and non-optimum. The view presented is that the problem is *not* how best to allocate our young men to serve in the armed forces, but rather, how best to allocate our *youth* in order to achieve the many and interrelated national objectives. The approach taken considers youth utilization as a resource allocation problem and suggests the use of mathematical programming. The technique leads to an allocation system where the burden of national service is made more equitable, where various forms of national service may be selected and where *all*

national objectives requiring the participation of youth are achieved. The author concludes that a national study team compressing the best operations research talent available be commissioned to examine the complete youth allocation problem and develop appropriate models and techniques to facilitate solution.

TA6.3 *A Residential Land Use Prediction Model, WALTER HELLY, *Polytechnic Institute of Brooklyn, 333 Jay Street, Brooklyn, New York.*

S. A. Stouffer's classic "Intervening Opportunities Model," for predicting the distribution of residential housing, is based on the sound assumption that the probability of exploiting a given building site is a monotonically decreasing function of the number of equivalent available sites nearer than it to the centroid of all such sites. However it is a time-independent formulation and so fails to account for the change in the number of available sites as time passes. Rather it assumes implicitly that all housing decisions over the extended prediction time span are made at the very beginning. The present paper offers a time dependent formulation, with explicit solutions for some simple urban forms. The new approach results in a better representation of near-saturation behavior when most sites are already exploited. It also permits studies of the effects of varying the time lags between construction decisions and the ultimate occupancy of the resultant structures.

TA6.4 *Alternative Decision Rules for Educational Evaluation: A Simulation Analysis, CHARLES SCHOTTA, JR., *Virginia Polytechnic Institute, Blacksburg, Virginia,* and CHARLES J. GOETZ, *Virginia Polytechnic Institute, Blacksburg, Virginia.*

The process of forming an educational evaluation may be likened to the quality control decision on a production line. In an earlier paper at the 31st National ORSA Meeting (BULLETIN, Vol. 15 (Spring, 1967), 39–40) one of the authors set out the theory of educational evaluation in these terms. On the basis of such an evaluation, additional resources are allocated to a student unit. It can be shown that the ultimate size and productivity of the stock of human capital which results from the educational process depends critically on the quality of the educational evaluations which select the individuals to receive further investment in human capital when the educational system is constrained in size as the level rises. Using a simulation model of a 20 stage educational process where the number of "places" in the process is reduced in successive stages, we test the effect of alternative decision rules for selecting the individuals to be incremented to the next level on the ultimate stock of "knowledge". Our results so far, based on analysis of 2000 "individuals", indicate that grading systems far less complex than the usual "A through F" categories will result in advancement decisions which are of higher statistical validity than the "A through F" system. We are also able to suggest several types of grade aggregation systems which are superior to the usual method of securing grade point averages. The object of our study is to shed light on educational evaluation decision rules which maximize the human capital output of the educational process.

TA7.1 *Comparative Analysis of Current Management Information Systems, MURRAY GREEN. *Communications and Management Systems, Cherry Hill, New Jersey.*

There is a Management Information System encompassed by the activities of every current company, regardless how small it may be.

Three basic elements normally comprise a Management Information Systems; (1) communications (2) data processing and (3) information files. The elements must be utilized in a combination and manner for setting forth an objective and useful vehicle for decision making in the operation of a business.

Large scale corporations are just beginning to realize that the real pay-off in the utilization of advanced equipments and techniques is for decision-making rather than just for accounting purposes. Organizational changes are being undertaken, highly technical personnel experienced in model, simulation techniques, system design etc., are being hired to design, develop and manage an MIS.

This talk will describe the make-up and utilization of various current Management Information Systems. In addition, the benefits by the applicable corporations accrued will also be a topic for discussion.

TA7.2 *Models of MIS Effectiveness, STEPHEN W. LEIBHOLZ, *President, Analytics, Inc., Camden, N. J.*

The proliferation of management information systems in the past few years has fostered a need for formal models to predict and measure their effectiveness, and to perhaps distinguish among them, with a view to selecting or optimizing designs or (if possible within the space of allowable decisions) determining whether one should be implemented at all. Since people are involved as the input sources and output users of most management information systems, this evaluation is sometimes difficult, involving as it does many assumptions about the needs and behavior of the managers involved. This paper reviews the definitions and models of MIS effectiveness that are available or adaptable, the latter mostly from models of information storage and retrieval systems and of computer system performance, with a view toward quantifying the decision processes inherent in an MIS development.

TP1.1 *System Design Criteria as Probabilities, B. OSTROFSKY, *TRW Systems, Redondo Beach, California.*

This paper presents the rationale for imbedding system design criteria in a multivariate probability space. The primary purpose of such an approach is to identify the performance of the optimal candidate system from a set of candidates synthesized during the feasibility study. Inference can then be made concerning the system which is theoretically optimum for the particular criterion space. The required conditions for the identification of the probability space are first, the accomplishment of a feasibility study and second, the preliminary design has progressed to the stage where analytical models of the criteria have been formulated in terms of system design parameters. The depth to which the criteria are modeled from the design parameters is assumed to be adequate for the ensuing computational procedures. An analytical form is offered which identifies a criterion function in terms of the joint probabilities of the various criteria.

TP1.2 *Toward a Method of Identifying Risk in Research and Development Tasks, ROBERT D. DOERING, *Hughes Aircraft Company, Fullerton, California.*

This study examines the risk inherent at the R & D task level—a task being the smallest element assigned to a responsible engineer. The task is viewed as a knowledge process with attainment of successive knowledge states along a time base representing the progress. Variables are defined which affect the time required for attainment of the state assuming that an adequate technical solution is feasible and adequate funds available. An analytical model is initially formulated using Markovian type transformation matrices for each knowledge state. Thus, given a knowledge state, the probabilities exist of moving to a higher state, remaining in the given state, or regressing to a lower state. These in turn are dependent on task variables. A model simulation is used to show the farreaching impact of a change in an individual transform probability. The variables are evaluated for sixteen historical R & D tasks through the use of comparative value estimation techniques, and a correlation-regression analysis for each state is performed with time as dependent variable. This data was used to structure a predictive model for time to attain each knowledge state given values for each variable available to the task. Total task time is obtained by addition of individual predicted state times; variance of total time includes variance and co-variance of state times. The validity of the model is tested on two tasks representative of laboratory activity which were evaluated in their planning stage. Faced with evaluation of a new R & D project task, management can use the model to derive an expression of risk inherent in the plan as the probability of exceeding the scheduled times. An expected loss for the task could also be assessed by applying the total task time probability function to a time-related cost function. Management can lower risk by adjusting some of the variables within its control.

TP1.3 *Planning R & D Projects Using GERT, A. ALAN B. PRITSKER and RONALD A. ENLOW, *Arizona State University, Tempe, Arizona.*

In this talk the problem of planning research and development projects using GERT is investigated. Research and development projects are characterized by logical building blocks which are used to describe the underlying structure of the decision process. Five milestones: problem definition, idea generation, evaluation, prototype, and implementation are defined, along with four basic activities: creative thought, time estimation, cost estimation, and evaluation. The use of GERT allows the manager to describe this creative process since GERT contains both logical and probabilistic concepts required for this type of model. A comparison with other network techniques is made by means of examples.

TP1.4 *Deficiences in Selected Control Systems with Special Reference to R & D, ARTHUR W. GUTENBERG, *University of Southern California, Los Angeles, California.*

Modern management control systems can be classified into a limited number of categories, each designed to provide control over a limited number of variables. Organization theory, as it relates to task or goal-oriented organizations, is based

upon a number of theoretical areas. A comparison of managerial control functions with prerequisites for control areas as dictated by theoretical considerations reveals a number of deficiencies in the controls. R & D type organizations, by their very nature, are complex. Therefore, these aforementioned control deficiencies are particularly meaningful in R & D type organizations, because only *effective* control can keep the organization functioning at an efficient level. Control deficiencies result from limited considerations given to certain theoretical areas. Other influences are completely overlooked, because they cannot always be quantified. Nevertheless, more areas must be considered and their influence recognized in the control process in the future.

TP2.1 The Optimal Bank Liquidity: a Multi Period Stochastic Model, HANS DAELLENBACH and STEPHEN H. ARCHER, *Department of Finance, Business Economics and Quantitative Methods, University of Washington.*

A Multi-Period stochastic model is used to compute the optimal cash balance of a bank. By a bank we mean a commercial bank or an international bank such as the United States holdings of gold and foreign exchange balances. The bank is assumed to have no legal minimal reserve requirements although this constraint could be introduced. The commercial bank cash balance is defined to include deposits in other banks, including the Federal Reserve. The model determines the optimal policy for adjusting cash on hand through (1) borrowing (Federal Funds, use of the discount window and repos for a commercial bank and the placing of U. S. Governments or borrowing from IMF for the U. S. Bank) and (2) security transactions (sale of bills for a commercial bank) given the random nature of the firm's uncontrollable cash flow overtime. The stockout cost is replaced with a decision variable P, the stockout probability management wishes to assume. It is formulated as a dynamic program.

TP2.2 *Valuation of New Product Proposals, PETER D. BENNETT, EAMON M. KELLY, and E. R. MELANDER.

The development of new products is generally recognized as an important management function, and in many industries, the crucial variable affecting the firm's success. The purpose of this paper is to present optimization models for the valuation of new product proposals under different decision situations. Models for the valuation of "conglomerate" new products are also developed.

TP2.3 *Some Empirical Evidence on the Use of the Sharpe Portfolio Model to Predict Efficient Sets of Portfolios, J. L. BICKSLER and J. MCGUIGAN.

This paper is an empirical test of the accuracy of the Sharpe model in predicting efficient sets of portfolios. The research design focuses attention on the 1946–1960 period and sub-periods within it. The data bank utilized is that of the Center for Research in Security Prices of the Graduate School of Business, University of Chicago and includes the requisite inputs for 208 securities. The corner points of the efficient sets are obtained historically and used as forecasts of future efficient sets of portfolios. Various insights into rational investment decision-making are deduced and their implications for portfolio selection are stated.

TP3.1 *Product Profit Optimization Considering the Managerial Decisions of Price, Marketing, and Inventory, DANA D. SQUIRE, *Manager, Mathematical Services, The Upjohn Company, Kalamazoo, Michigan.*

The basic underlying assumption of this research is that a prime motivation of an enterprise is the maximization of profits. The management dilemma is defined as determining a combination of price, marketing expenditure, and inventory level which maximizes product profit. A solution to this dilemma is a deterministic profit optimization model which simultaneously considers these managerial decisions.

TP3.2 *Sales Forecasting with an Adaptive Model, HUGH E. BRADLEY' *Senior Operations Research Analyst, Mathematical Services, The Upjohn Company, Kalamazoo, Michigan.*

The Theil-Wage three-factor adaptive forecaster (*Management Science*, 10, 2, Jan. 1964) extended by introducing a more general trend change term. Parameter estimation, stability, transient response, and the effect of initial conditions are considered. This forecaster is used to predict sales of a variety of products: promoted and non-promoted, seasonal and non-seasonal. Predictions are made monthly as far as 24 months ahead. Good fits, with correlation coefficients in excess of 0.9, are realized.

TP3.3 *Technical Planning, DONALD T. ASHER, *New Product Evaluation, Abbott Laboratories, North Chicago, Illinois 60064.*

A major gap in long range corporate planning has been the inadequacy of technical planning and the consequences of future technological progress on present day decisions. Our interest in technological forecasting (TF) is twofold: (1) as a useful discipline in strategic planning; and (2) as an input for the technical planning process. Given a TF in which there is a high degree of confidence, what are the implications for R/D? How can the relevant factors be integrated into a meaningful technical plan? The R/D director is confronted with a resource allocation problem in choosing a portfolio of projects. In addition, the technical plan must consider: (1) the technological breakthroughs anticipated and their impact on R/D efforts; (2) the corporate characteristics which the company should possess in the next 5–10 years; and (3) an assessment of R/D goals as a part of corporate goals. The interchange and feedback with R/D, marketing, and finance should enable us to develop a technical plan which reflects the needs of the future as to new products, product improvements and new areas of technology. Examples and experience with this technical planning process will be discussed.

TP4 Operations Research in Engineering Design

This session is being planned to reflect the increased activity in Operations Research within the engineering communities, particularly with respect to problems of design.

TP5 Workshop on O.R. Applications in Space Operations Management.

An important objective of designers of space station system subsystems is to ensure that the results of their efforts will add to the total system capability for

near-optimal control of all flight operations and experiment activities. This control must be continuous. It must extend throughout the pre-flight, in-flight, and post-flight mission phases. To provide this control a command and control system is required. Such a system may be referred to as the Space Operations Management System (SOMS). In the forthcoming Workshop, a concept-of-operations for a SOMS will be presented by the Workshop Chairman together with some hints on how this conceptual model can be used as a context in which many space station studies and design activities can be related. This SOMS concept-of-operations will be used by an expert panel as a framework for relating their discussions of selected core problems that emerge during the design, development, test, or operation of a space station system. The panel members may or may not offer approaches which may yield solutions to the problems identified. In either case, the audience will be asked to contribute to both the identification of core problems and to solutions which may be expected to result from the application of OR techniques.

TP6.1 *Nursing Manpower Program Analysis, JEFFREY H. WEISS, *Office of the Secretary, Department of Health, Education and Welfare, 330 Independence S.W., Washington, D.C. 20201.*

This paper evaluates alternative HEW programs relating to professional nursing manpower. The purpose of this analysis is to indicate relative priorities among the various program elements designed to achieve specific objectives and to develop the rationale for emphasizing one objective relative to another. In most cases, the dynamic nature of the problem and data limitations do not permit precise calculations about the prospective benefits from a specific program element, or set of program elements. Instead, it was necessary to qualitatively indicate the most likely effect of particular program elements. Further, a model of the basic nurse education system was developed to explore how the future output from the basic programs might vary according to alternative assumptions about the nature of the system. This model provided some indication of how future faculty and student constraints might limit the rate of expansion of the output from these educational programs.

TP6.2 The Technological Limit to Air Quality, ELLISON S. BURTON and WILLIAM SANJOUR, *Ernst & Ernst, 900 17th Street, N.W., Washington, D.C. 20006.*

A comprehensive simulation approach is discussed which allows air pollution abatement strategies to be compared to the most cost-beneficial strategy for achieving various air quality levels of selected pollutants. Several possible exposure functions are introduced which permit strategies to be developed for selective abatement of damaging wasteloads. Various strategies are then evaluated for their efficiency in reducing human exposure to sulphur dioxide and suspended particulates in actual applications of the simulation approach. By projecting some possible changes in fuel use, in power generation, and in improved collection efficiencies for pollutant emission control devices, the future technological limit to air quality and human exposure with respect to sulphur dioxide and suspended

particulates can be estimated. The applicability of this method of analysis to other pollutants is also discussed.

TP6.3 *An Analysis and Comparison of the Provision of Pediatric Services, GILBERT BERNSTEIN, *Health Services Administration, City of New York, 125 Worth St., New York, New York 10013.*

This study outlines an analysis made by New York City's Health Services Administration comparing alternative modes of delivery of pediatric services. The relative costs and outputs of providing services in a well-baby clinic, a hospital out-patient department setting, and an ambulatory care center are presented. The study compares the cost, content, and output at alternative levels of funding. The impact of alternative financing schemes on the city's ultimate out-of-pocket costs is highlighted in this analysis. The results of this study are expected to be implemented in the fall of 1968. The City intends to monitor and evaluate the project on an intensive basis on the hope of applying this analysis in its other pediatric service settings.

TP7.0 Workshop in the Art of Simulation, *Chairman:* STEPHEN LEIBHOLZ, *President, Analytics, Inc.*, JOHN DECANI, *Associate Professor of Operations Research and Statistics, University of Pennsylvania*, FRANK MILILLO, *Head of Command Support Research Branch, U.S. Naval Research Laboratory*, MORRIS PLOTKIN, *Associate Research Scientist, University of Pennsylvania*, and HAL TREMBLAY, *Chief of Computing and Simulation Division, U.S. Naval Air Development Center.*

"Simulation," Voltaire is reputed to have said in 1775, "is the last refuge of the incompetent." Perhaps due to the fact that the art of simulation has enjoyed increasing success in solving a broad range of problems otherwise unapproachable, its practitioners are becoming increasingly aware of a widespread tendency to regard simulation as a panacea for problem solving and a handy replacement for analysis. This Workshop will examine the techniques and applications of simulation with the purpose of exposing criteria for their use, the criteria for selection of particular simulation methods in each application, and the criteria for interpretation of the results. Thus, for example, while considerable literary efforts have been devoted to statistical criteria for terminating Monte Carlo calculations, this Workshop will examine, among other things, the criteria for terminating one before the first iteration. Each attendee is expected to contribute a brief summary of his interests and activities, as well as questions and comments for the panelists.

FA1.1 *Process Optimization Using Nonlinear Programming, HENRY J. MORRIS, *Monsanto Company, St. Louis, Missouri.*

The problem of determining the optimum set of steady state operating conditions for a chemical plant can be considered a nonlinear programming problem. It involves the calculation of the minimum (or maximum) value of an object function subject to a set of equality and inequality constraints with the independent variables having upper and lower bounds. The object function could be the cost of operating the process. The equality constraints come from the material and heat balances for the system, as well as the chemical reaction and heat transfer

relationships that must be maintained. The inequality constraints are a consequence of the equipment capacity limitations, temperature and pressure limits, product quality and waste stream specifications. Several nonlinear programming techniques have been applied to a mathematical model of a hydrogen reforming unit for an ammonia plant. Some of the problems of developing a simulation model which adequately describes the system and can be used in nonlinear programming are discussed and the performances of the techniques compared.

FA1.2 *Determination of Near-Optimal Policies by State Variable Approximation, R. L. ZAHRADNIK, *Carnegie-Mellon University, Pittsburgh, Pennsylvania.*

The paper discusses the determination of near-optimal policies which approximately maximize a time-integral performance criterion involving both policy and state variables. The policy and state variables are further related by differential equation constraints. The method involves the immediate approximation of the optimal state trajectory by means of a set of trial functions and mixing coefficients. This reduces the performance criterion integrand to a function of the policy variable, the mixing coefficients, and time. The near-optimal policy is the one which maximizes this integrand for all time in the given time interval and is expressible in terms of time and the mixing coefficients. The mixing coefficients may be found by application of one of the approximation function methods, such as the Galerkin method, to the constraint differential equation. Examples are presented to illustrate the method.

FA1.3 *Results and Methods in the Risk Oriented Investment Decision, ARTHUR STUENKEL, *Corn Products, Englewood Cliffs, New Jersey.*

Corn Products' experience with an investment risk analysis system will be presented. The company and its investment approval process will be described. The organizational environment dictated the need for a management decision oriented system. The system simulates possible investment states of nature via distributions of key investment variables estimating profitability with the return on investment algorithm. A history of our successes and problems leads to recommendations of strategy and tactics which can assist in effectively installing a management model.

FA1.4 *Design of Corporate Strategic Studies, ROBERT B. GRANT, *Celanese, New York, New York.*

The conduct of strategic planning processes utilizing a model structure is presented with reference to a large decentralized business. Concepts of a formal corporate planning program are introduced. Using these as a framework, the role of analytical models in strategic analysis is discussed. Conceptual difficulties in the introductory phase, and implementation problems in the operational phase are outlined. Display of decision information and procedures for maintenance of active key alternative study data are summarized.

FA1.5 *The Role of Cardinal Utility Theory in Decisions Under Risk, RALPH O. SWALM, *Syracuse University, Syracuse, New York.*

Of fundamental importance in any decision is the choice of criteria. While most would agree that the most promising criterion for decision under risk is the optimization of utility, there is but limited evidence regarding the effectiveness of attempts to make use of this concept in industrial applications. This paper will present the results of a continuing research project on industrial applications of cardinal utility theory and discuss parallel research carried on by others.

FA2.1 *Speed Estimation from a Moving Automobile, LEONARD EVANS, *General Motors Research Laboratory, Warren, Michigan.*

Eighteen subjects were driven seated in the passenger seat of a car whose speedometer was hidden from their view. The subjects' task was to estimate the speed of the automobile under four different conditions of sensory awareness. These were: (A) Normal passenger, (B) Unable to see—the subject wore a blindfold, (C) Impaired hearing—the subject wore a noise excluder, (D) Subject wore both the blindfold and the noise excluder. Under all four conditions slow speeds (25 mph or less) were significantly underestimated. Comparing total performance under the different conditions led to the following conclusions. Under conditions A and B, the subjects estimated normal driving speeds without systematic error. For those conditions involving impaired hearing, (C and D) all speeds were significantly underestimated, indicating that the sense of hearing is of great importance in the task of estimating speed. A follow-up experiment was conducted in which a larger number of subjects watched a silent movie film shot from the same car as used in the above experiment. The results obtained from the movie most resembled those obtained in the first experiment when the subjects hearing was diminished. It was also observed that the subjects seated near the screen made *lower* estimates of the speeds than those seated far from the screen. This phenomenon is readily explained by an elementary perspective argument.

FA2.2 *Highlights of the Fourth International Symposium on the Theory of Traffic Flow, RICHARD ROTHERY, *General Motors Research Laboratory, Warren, Michigan.*

The Fourth International Symposium on The Theory of Traffic Flow was held at Karlsruhe University from June 18–20, 1968. Papers presented at the meeting covered a variety of traffic phenomena relating to single-lane traffic flow, multiple-lane traffic flow, networks, intersections, economics, trip generation and traffic assignment. This paper presents the highlights of this symposium.

FA2.3 *An Analysis of the Boltzmann-Type Statistical Models for Multi-Lane Traffic Flow, P. MUNJAL, *System Development Corporation, Santa Monica, California,* and J. PAHL, *University of California, Los Angeles, Los Angeles, California.*

There seems to be a great deal of controversy over the concept of applying the methodology of the kinetic theory of gases to the description of traffic flow on multi-lane highways. Therefore this paper reviews critically the series of publications describing the Prigogine *et al.* Boltzmann-type statistical models for multi-lane traffic flow. The basic and the generalized Boltzmann-type equation for

traffic flow has been derived with more emphasis on the physical meaning of the analytical derivations with respect to the traffic context. An attempt has been made to clarify and critically review the hypothesis and assumptions made by Prigogine *et al.*, and to present their basic material in a more readable form. This has been supplemented with detailed analysis and critiques. The mathematical foundation on which the relaxation, interaction and adjustment processes are based have been evaluated in depth. The role of these three processes with respect to the traffic context is then evaluated, and their ability in describing the vehicular traffic flow on the multi-lane highways has been discussed.

FA2.4 *Case Study in the Application of a Traffic Network Simulation Model, FRANK C. BARNES and FREDERICK A. WAGNER, JR., *Planning Research Corporation, Los Angeles, California.*

A digital computer simulation model of traffic operation and control on urban street systems was utilized to investigate the effectiveness of several traffic engineering alternatives in a hypothetical nine intersection 3 by 3 grid network. The network studied consisted of two intersecting major arterial streets and the parallel minor streets along each side. Four alternatives were considered: (a) the existing conditions; (b) prohibition of left turns on the major arterial streets; (c) parking prohibition and left-turn channelization on the major arterial streets; and (d) grade separation at the intersection of the two major arterial streets. Simulation exercises were made representing six levels of traffic demand on the arterial streets. The resulting operational characteristics of the traffic system under each of the alternatives are compared. Utilization of statistics from simulation experiments for economic analysis of traffic engineering alternatives is briefly discussed.

FA2.5 Increasing Expressway Utilization for Motorists, RICHARD H. HAASE, *College of Business Administration, Drexel Institute of Technology, Philadelphia, Pa. 19104*

A follow-the-leader model of traffic flow is employed to investigate possible methods of increasing the utility of freeways. The criterion used is that of *minimizing trip travel time*, since this is the motorist's primary objective, rather than maximizing flow. An idealized model of a typical freeway trip shows that travel time may be reduced by maintaining the density of cars below a critical level. This can be accomplished by restricting the flow of cars onto the freeway and by maintaining off-ramp capacity in excess of on-ramp capacity.

The study also suggests for further analysis three technical developments that may increase the utility of freeways:

1. An effective integrated control system to regulate the density of automobiles on the freeway network.
2. A practical method for automatic lane reversal.
3. An efficient, fast method for removal of obstructions on the freeway.

FA3.1 *Applying Metagame Theory to the Vietnam Conflict, NIGEL HOWARD, *Management Science Center, University of Pennsylvania, Philadelphia, Pa.*

Metagame theory starts from a game in normal form in which the players, payoffs may be replaced by general "preference relations" between the outcomes (strategy n-tuples). We look for "policies" (functions from the others' strategies to one's own) and "counter-policies" (functions from these functions) by which players can influence each other to accept various outcomes. The technique is applied to find which outcomes of the Vietnam situation might be made "acceptable" to all parties.

FA3.2 *Optimizing Strike Force Planning, PAUL L. GRAY, *O. R. Analyst, USAF, Operations Analysis Office, Washington, D. C.*

This paper deals with planning, scheduling and decision-making as related to the use of tactical air forces in Southeast Asia or in any limited or general conflict. The primary emphasis is directed toward utilizing state-of-the-art automated data storage and computer programming in support of strike force planning. Some data storage concepts are being employed but there has not been any directed effort toward developing computer software. Programming is needed to fully utilize the data and to support tactical planning and directing of strike forces. Therefore, this paper outlines and recommends three incremental levels of effort: 1. Establish in-house programming skills to develop a daily operations order (frag) generator with remote console print-out at using tactical air installations. 2. Develop programming to fully support command decision making. The possibilities include testing of options, the maximization of strike force effectiveness, pin pointing limiting parameters and sensitivity analysis. 3. Expand and integrate existing computer resources to provide centralized computer support for all command functions in the combat theatre. This could include combat reporting, intelligence, supply, airlift, etc. In summary this paper outlines a method to bring planning and directing techniques up to the capabilities of weapon systems in use. Substantial gains are possible when Commanders become aware of, and use, contemporary computer resources.

FA3.3 *Optimal Allocation of Air Strikes for Interdiction of a Transportation Network, THOMAS M. MUSTIN and ALAN W. MCMASTERS, *Department of Operations Analysis, Naval Postgraduate School, Monterey, California 93940.*

Under certain conditions, the resupply capability of a combatant force may be limited by the characteristics of the transportation network over which supplies must flow. Air strikes by an opposing force may be used to reduce the capacity of that network; the effect of such strikes vary for differing missions and targets. With only a limited number of sorties available, the strike planner must decide which targets to hit and the number of sorties to allocate to each. An algorithm is presented for determining the optimal strike plan for minimizing network flow capacity.

FA3.4 *Time-Dependent Predictions of Guerilla Actions, RICHARD C. MOREY, *Stanford Research Institute, 333 Ravenswood Avenue, Menlo Park, California 94025.*

This paper concerns itself with the question of whether or not, based upon past observations of guerilla-initiated actions in South Vietnam, one can predict with any degree of confidence the levels of various types of actions throughout the day. The question can in part be answered by determining if these guerilla warfare phenomena are under so-called "statistical control", or equivalently, by discerning if there exists an approximately constant system of chance causes, either known or unknown, which determine the particular events observed. Examples of chance causes might include illness, morale, weather, etc. The system goes out of control statistically when "assignable" causes such as a change in force levels or tactics perturb the chance cause system. Control charts were used to monitor these phenomena, allowing one to detect changes both in the levels and in the variabilities of the various processes. The data analyzed were the monthly totals of the various guerilla-initiated actions in South Vietnam in each of five time periods of the day. The study also investigated correlations, for example, between the levels of action in the late morning and in the afternoon, and in any relationships involved with the lunar periods. The value of the model then is to enable the observer to make more valid predictions, and to systematically record the enemy's responses to changes in strategy.

FA3.5 Evaluation of Logistics Support Alternatives for Tactical Fighter Aircraft under Combat Conditions, CHARLES L. MOOR AND JAY WILLIAMS, *Operations Analysis Office, Air Force Logistics Command, Washington, D. C.*

The paper describes the Air Force "PACER SORT" project, a large scale data collection, analysis and simulation effort to evaluate the impact of logistics resource substitution in a combat environment. The logistics functions and weapons operations of a four squadron F-4C wing were instrumented to provide the data base. Two squadrons were used as the control group and two received the experimental treatment. The project is reviewed in terms of its immediate objectives, the data collection problems encountered and the overall conclusions that resulted from the effort. It is concluded that the logistics support resource requirements are, in effect, fixed during the design of the weapon system. That is, the operating hardware and AGE interaction and design, coupled with the maintenance plan and organizational arrangement establish the requirements. Subsequently, minor adjustments can be made; however, the impact is relatively inconsequential when compared with the options open during design.

FA4.1 *Common Patterns in Educational Planning Models, JOSE GLASSERMAN, *IBM, 2651 Strang Blvd., Yorktown Heights, New York 10598.*

During the past few years a number of planning models have been developed for education. These models have focused on a number of different areas in the field, but appear to be conceptually and structurally related among themselves as well as with models in other fields. Understanding these relationships is of special interest in transferring techniques of analysis developed in other fields to the field of education. A four-part structural pattern, commonly found in educational planning will be presented and illustrated with examples. The parts are: 1. Building an adequate description of present and/or future enrollment patterns.

2. Structuring the available and/or projected resources and facilities (e.g. staff, schools) and their associated costs. 3. An algorithm for the process by which students are assigned resources and facilities (e.g. scheduling, zoning) within a number of prespecified constraints. 4. An evaluation through which figures of merit (effectiveness) are assigned to configurations described in the first three steps.

FA4.2 *Cost-Effectiveness Analysis and Educational Policy—Profusion, Confusion, Promise, HENRY M. LEVIN, *Research Associate, The Brookings Institution, 1775 Mass Avenue, N.W., Washington, D. C. 20036.*

This paper will tentatively address itself to the large number of recent cost-effectiveness studies which have been undertaken in the quest for making more rational decisions for the schools. An assessment will be made of some of the problems that face the operations researcher when he applies his techniques to education. Specific attention will be paid to conceptual problems, quantification difficulties, and the communications gap that permeates the relationships between operations researchers and educational decision makers.

FA4.3 *Adaptation PPBS to a Decentralized Strategy, OLIVER S. BROWN, *School District of Philadelphia, Board of Education. Parkway at Twenty-First Street, Philadelphia, Pennsylvania 19103.*

The presentation is essentially a progress report on the application of PPBS in the Philadelphia School District. Included will be a discussion of the System-wide program—Goal Matrix, its use, problems in defining goals and objectives, problems in defining and monitoring program ompact, progress in the application of PPB within a decentralization effort, and the presentation of the financial management model which attempts to redefine relationships among the several levels of the organization. Illustrative material from the actual PPB planning documents for the 1968–69 fiscal year will be utilized.

FA5.1 *The Application of OR to Criminal Justice, ALFRED BLUMSTEIN, *Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia 22202.*

The criminal justice system, comprising the agencies of police, courts, and corrections, is charged with reducing crime while safeguarding basic liberties. There is a wide range of opportunities for the applications of operations research to the management and operation of these agencies and to the examination of basic questions about crime and the effects of the crime control system on it. These include integrated examination of the total criminal justice system; allocation of resources among agencies and within the individual agencies; the allocation, assignment and scheduling of personnel; the processing of cases through the court "production" process. In more basic terms, there is the fundamental problem of developing the relationships between crime and the many kinds of actions taken to control it. This paper summarizes the current primitive state-of-the-art in this area of application, raises many questions, and indicates some of the OR approaches needed.

FA5.2 *The Delphi Method, N. C. DALKEY, *Rand Corporation, Santa Monica, California.*

Delphi refers to a set of procedures for aggregating and refining the factual judgments of a group of knowledgeable individuals. The procedures involve the use of questionnaires in an iterative exercise with controlled feedback of information between rounds, and the use of a statistical representation of the group response. The major features of such an exercise are: (1) *Convergence.* Initially widely divergent opinions tend to narrow from round to round, (2) *Improvement in accuracy.* For material where the accuracy can be checked, more often than not the group response improves in accuracy with iteration. The procedures have been applied in a number of areas where expert opinion is the only practical method of obtaining useful judgments such as forecasting long range technological and social events. An extensive series of experiments has been conducted at RAND to establish the properties of the Delphi process and to evaluate modifications of the procedure. The results of these experiments will be reported and discussed.

FA5.3 Application of O.R. to R & D Management, BURTON V. DEAN, *Department of Operations Research, Case Western Reserve University, Cleveland, Ohio.*

Increased attention is being given to decision problems in R and D management by operations researchers. Mathematical programming models and techniques are being developed to solve resource allocation problems in the cases of independent and interrelated research projects. Another method for analyzing R & D budgeting problems is through a statistical evaluation of historical cost data and a transfer coefficient method for estimating future budgets. Current investigations are concerned with modifications of development budgeting models to include stochastic aspects and a simplified queueing network model of the project flow in a multi-section department of a development oriented R and D organization.

FA5.4 *The Probabilistic Aspects of Long-Range Planning, DAVID B. HERTZ, *McKinsey & Company, Inc., New York, New York.*

Long-range plans for corporations and governments have traditionally been developed on either single-point estimate, range, or contingency bases. Further, it is often felt that the rolling nature of the planning process permits the effective use of single-point estimates or ranges, since the plan is changed periodically in the face of changing external and internal circumstances. However, there is no assurance when such plans are made that the uncertainties inherent in each of the factors that affect the end result objectives are adequately considered. Thus, planning programs that allow for the incorporation of uncertainty profiles covering the life of the plan will permit these end results to be examined in terms of the distributions of their outcomes. This paper describes an approach to long-range planning that permits flexible examination of alternatives in terms of the expected values and variances of the results. Applications of this approach to public and private planning will be considered. These same considerations may also be applied to shorter-range budgets.

FA5.5 *Optimal Sequencing of Jobs Subject to Deadlines, E. L. LAWLER and J. M. MOORE, *The University of Michigan, Ann Arbor, Michigan.*

There are a number of problems involving the sequencing of jobs subject to deadlines for which a certain "consistency principle" holds. This paper demonstrates how this principle can be exploited to obtain extremely efficient dynamic programming solution methods for the following problems: (1) a single machine and jobs with individual deadlines, (2) the same problem with partial ordering restrictions on the sequence, (3) two machines in series and jobs with a common deadline, and (4) a single machine, jobs with a common deadline, and linear deferral costs. Generalizations for partial ordering restrictions and many machines in parallel are also discussed.

FA5.6 *Theory and Applications of Generalized Polynomial Optimization, DOUGLASS J. WILDE, *Stanford University, Stanford, Calif.*

A theory for optimizing generalized polynomials, highly nonlinear functions occurring frequently in engineering and economics, subject to generalized polynomial constraints, has recently been developed. It is an extension of the Geometric Programming theory of Duffin, Peterson, and Zener to functions having negative terms as well as positive ones. This survey will describe the theory and applications developed by U. Passy, M. Avriel, and G. Blau since 1966.

FA6.1 A Computerized Cost Model for Space Systems, LEONARD Y. SHAKT, *Missile and Space Division, General Electric Company, King of Prussia, Pa.*

A unique cost model has been developed based upon estimates of spacecraft subsystem weights and complexities. Regression equations have been determined for each subsystem, based upon historical data, for the following cost elements: Design and Development Costs, First Unit Costs, Investment Costs for Ground Facilities, Launch Costs, Operational Costs, and Total Program Costs. State-of-development judgment factors are included to allow for cost reductions for subsystems that require varying levels of modifications in design and development from previously developed subsystems. The model is programmed for a time/sharing computer and permits rapid iterations by the user to determine cost sensitivities with subsystem design variations. Regression equations are based on a historical data bank and are continually updated as new data becomes available.

FA6.2 Probability of Biological Contamination of Mars, ANDREW UNGAR, *Matson Research Corp., 100 Mission Street, San Francisco, California 94105.*

One of the requirements associated with plans for unmanned biological experiments on the surface of Mars is a low probability of contaminating the planet with microorganisms from the experimental vehicles themselves. A simple probability model, based on a Voyager mission profile, has been formulated, and a sensitivity analysis has been performed to determine the influence of the important events in the mission on the probability of contamination. There have been laboratory experiments to determine the ability of various microorganisms to grow in a simulated Martian environment, but the question of what would constitute contamination remains open. It is also left open in the model. Only one event between the

launch of a vehicle and the landing of an experimental capsule has significant influence on the probability of contamination. This is the probability of recontamination of a sterile capsule when its flight shield is removed in space. The probability of a soft landing and the values of the probabilities of contamination associated with the type of landing are also critical factors. Increasing the number of missions from 10 to 25 has the effect of increasing the overall probability of contamination between two- and three-fold.

FA6.3 Methods of Optimizing Satellite Communications Networks, GEORGE E. BOWDEN, ROBERT C. MOORE and WILLIAM R. MINTY, *Philco-Ford Corporation.*

This report covers an investigation of methods for optimizing operation of a communications network which uses a single, hard-limiting, multiple access satellite as a relay on all links, and which may use either frequency division, time-division or spread-spectrum multiple access techniques. Alternative methods based on dynamic programming techniques and on Lagrange multiplier analysis have been developed for each multiple access technique, and have been programmed in Fortran IV. The initial work on this investigation was covered in RADC Technical Report 67-144 (AD 814-488). This work is briefly described in the current report, and then various generalizations are established. Several alternative optimization criteria are developed to complement the four previously used. Optimization methods are developed to apply to a network in which the traffic may have as many as six levels of precedence. New methods are also developed to apply to networks in which the distribution of message lengths is general and to those in which some or all channels must handle regularly scheduled traffic in addition to random arrival traffic. Computer programs to implement all of these generalizations have been written and are described in detail in an Appendix to this report. Another Appendix contains investigations of the theoretical performance of the TATS modem proposed for use in the tactical satellite program and discusses the application of the optimization methods developed to networks in which this modem is used.

FA6.4 Cost-Effective Selection for a National Space Launch Vehicle Stable, ROBERT E. DROWNS, *Design Specialist, Advanced Applications, LVP, Mail Zone 952-40, General Dynamics/Convair, Box 1128, San Diego, California 92112.*

Significant economies can be attained within our space program if we judiciously select a cost-effective National Space Launch Vehicle Stable. This paper presents a methodology for the optimum cost-effective selection of space launch vehicles by management. This systematic approach to the development of standard launch vehicles is based on the minimization of the federal government's expenditures while concurrently attaining the mission goals which have been established. This methodology will also provide a management tool to: (1) evaluate the effect of the launch vehicle mix; (2) evaluate the utilization of launch vehicles (and stages); (3) determine the effect of increasing (or decreasing) the available launch vehicle inventory; and, (4) evaluate the degree to which proposed launch

vehicle performance improvements are economically efficient. Industrial management can also benefit from this operational analysis approach by; (1) evaluating utilization (potential sales) of existing and proposed company products; (2) identifying cost-effectiveness of the competition; and, (3) determining the extent to which product performance should be improved. A computer simulation, MAP, has been programmed for evaluation of the aerospace launch vehicle market, and examples are presented of the utility of this versatile management tool.

FA6.5 A Nondemographic Factor V/STOL Prediction Model, ALEXIS N. SOMMERS and FERDINAND F. LEIMKUHLER, *School of Industrial Engineering, Purdue University, Lafayette, Indiana, 47906.*

A model is described for predicting the market shares of V/STOL aircraft in competition with automobiles and conventional airliners in future short haul intercity business travel markets. A mode choice theory is presented which defines market shares as linear functions of the nondemographic factors of total door-to-door travel time, convenience, safety, weather reliability, comfort, and total cost. Data collected by a mode choice questionnaire indicates that these six nondemographic factors uniquely determine the mode choices of a businessman sample for a short haul market segment composed of three large Midwestern cities. It is shown that two types of V/STOL aircraft, an advanced helicopter and a tilt-wing, operating in a 1985 business travel environment, are expected to jointly seize market shares of between 48% and 66% in competition with future CTOL airliners and automobiles. The prediction theory and technique is expected to be useful to those aerospace and transportation industries concerned with planning, developing, and financing futuristic transportation systems.

FP1.1 *Prices and Profits, JOHN M. BRAGG, *Life Insurance Company of Georgia, 600 West Peachtree Street, N.W., Atlanta, Georgia 30308.*

This paper describes a merchandising oriented approach for determining prices and sales compensation. Competition and other factors affecting sales are considered. While the methods described are applicable to any product or service that is sold, special attention is given to the sale of the products of a life insurance company and the determination of optimum premium and commission rates.

FP1.2 *Prices and Profits in Property and Liability Insurance, DAVID M. BOODMAN and IRVING H. PLOTKIN, *Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts 02140.*

In the highly regulated property and liability insurance field disagreement arose about the proper treatment of investment income in setting premium rates. Analysis showed that the real question was the propriety of the rates charged, or or the adequacy of the total income received, two different aspects of the same question. An objective means of examining this question was developed. Its application seems to have disposed of the original controversy.

FP1.3 *Collective Risk Theory, PAUL M. KAHN, *Equitable Life Assurance Society of the United States, 1285 Avenue of the Americas, New York, New York 10019.*

This theory yields the probability distribution of total losses from an aggregate of individual independent risks. The amount at risk and the probability of loss associated with each individual risk may be unique. Various methods have been developed for calculating the distribution of total losses. Applications include premium, dividend and contingency fund calculations for group insurance and calculation of pure premiums for stop-loss reinsurance.

FP1.4 *A Flood Insurance Model, TAPAN ROY, *The Travelers Insurance Company, 1 Tower Square, Hartford, Connecticut 06115.*

Flood as a natural phenomenon has caused millions of dollars of damage every year in the United States. Because of the high risk involved, no flood insurance is available in the market today. The present study involves the determination of a joint federal government and industry flood insurance program. Because of the sparseness of data, the usual actuarial techniques of retroactive study were not possible. Simulation techniques were used for a statistical study of the natural hazard, from which a financial model was built to answer pertinent questions as to rates, share of the market, government subsidy, reinsurance and capital requirements.

FP1.5 *Optimizing Debit Size, DWIGHT K. BARTLETT, III, *Monumental Life Insurance Company, Charles & Chase Streets, Baltimore, Maryland 21202.*

In the type of operation considered a single agent is assigned exclusive responsibility for the sale and service of all of a company's individual insurance in a carefully defined geographical area, called a debit. Various elements of the company's operations, the termination rate of agents, the length of time a debit remains open between the time an agent terminates and the time his replacement is hired, and the production and termination rates of business assigned to the debit, seem affected by debit size and also affect a company's profit. This paper examines the relationships involved and proposes a method for determining the debit size that optimizes profit.

FP2.1 *Simulation of a Private Line Communications Network and a Real-Time Management Information System Network, MARVIN AMES, *Sinclair Oil Corporation.*

This presentation covers the background, development and implementation of two GPSS Simulation Projects. 1. A simulation model was developed for Sinclair's Private Line Communications Network. This network includes sixty terminals connected by Company owned and operated microwave circuits and AT & T Telpak Systems. The model was designed to evaluate current networks and to assist in designing future systems. 2. A simulation model was used to assist a Feasibility Task Force to propose and evaluate a real-time management information system for a major company division. This system will provide on-line real-time information for marketing, distribution, inventory control, accounting and credit applications. The model was developed to meet three primary objectives: A. Test the performance of the systems proposed by manufacturers. B. Provide assurance that the selected system will work effectively under proposed

loads. C. Indicate the amount of computer time that will be available for processing non real-time applications.

FP2.2 *Seeking of Optimum Well Spacing and Production Systems in Oilfields, P. MUNJAL, *System Development Corporation, Santa Monica, California.*

The paper describes the early concepts of optimum well spacing and production systems and then discusses in detail the modern concepts in tackling this complex problem. On the basis of these modern concepts, an exhaustive mathematical model for the above system has been described. This mathematical model was then incorporated into a computer simulation package which has been developed to seek the optimization of well spacing and production systems in oil fields. Some of the parameters which have been built into the above model include the expected reservoir production history, recovery factor, investment type, stock tank oil in place, initial maximum well potential, total reservoir production target, discount rate, tax type, starting production time, number of drilling rigs, average number of days required to drill and complete a well, realized and posted crude prices, etc. On the basis of the above parameters, the model computes the different management decision making quantitives, which include the optimum well numbers, discounted net cash flow, total cumulative oil production and investments, average cost of oil production, economic and payout time, oil field drilling production schedules, etc. The model also determines quantitatively the effects of not developing the oilfield under optimum conditions, should the management decide under some overriding or legal considerations. It has been shown that there exists an optimum sustained reservoir production target for a given oil field, and there exists an optimum well number corresponding to this optimum reservoir sustained production target.

FP2.3 *Reservoir Simulation Models, RUDOLPH W. BUCHWALD, THOMAS L. SPRATT and HOWARD L. TAYLOR.

The general development and form of Reservoir Simulation Models in Petroleum Engineering is presented. Their use in optimizing or improving reservoir performance is discussed. Examples of studies and improved profits are cited. Future requirements for reservoir modeling and O. R. concepts in oil field optimization are considered.

FP3.1 *Cost/Benefit Analysis Applied to the Design of Commercial Air Transport-Type Aircraft, G. A. BUSCH, *Lockheed Aircraft Corporation, Burbank, California.*

The techniques of systems analysis are used by the design team to help assure that the sub-optimization of the aircraft promotes the optimization of the entire transportation system. In this process, cost/benefit analysis has several applications: 1. *In projecting the characteristics of the demand for commercial air transportation service.* The potential users of passenger or cargo transportation service tend to choose from among the alternative public and private transportation modes available that mode which will minimize their total costs, including the imputed

value of the cost of time in the transportation cycle. Linear programming techniques are useful in quantifying the aggregate results of the myriad cost/benefit decisions made by potential shippers. 2. *In projecting the characteristics of supply of air transportation service.* The airline operator, in adding to or modifying his fleet of aircraft, will select from among available alternatives the aircraft which offer superior return on the investment, taking into account the present worth of projected future earnings. 3. *The aircraft manufacturer's decision to produce a new aircraft.* Among the important elements in a manufacturer's decision to go forward with a new commercial aircraft program is a careful assessment of the present value of the total costs associated with the program, the total benefits or revenues associated with the program and the indicated rate of return. 4. *Aircraft Design Trade-offs.* The design team, in making trade-offs, will consider not only the direct costs and benefits of a design change on payload, range, speed and unit direct operating costs, but also the affect on community noise, airport congestion, airspace utilization, airline return on investment, etc.

FP3.2 *Program Structure and Cost/Benefit Analysis in Transportation, ALLEN R. FERGUSON, *Planning Research Corporation, Washington, D.C.*

Program budgeting injects economic analysis into the midst of the budgetary process. However, it has evolved into four unfortunately rather separate activities: The old-line budgetary process, the construction of approved program structures, performing analysis, and developing data and information systems. This is partly a consequence of institutional rigidities and professional parochialism, but it is also partly the result of failure to understand fully the relationships among these four processes. This paper deals with the relationship between program structure and the relevant analyses. It points out that the extent to which budgets are likely to be based on relevant analysis depends substantially on the program structure. The structure should delineate the nature of the trade-offs performed in generating program memoranda. The question of what structure is appropriate then depends on what trade-offs one wants to force. For example, in transportation the analytic process will be considerably different, at least in sequence, depending upon what trade-offs the structure imposes. Several possible structures are outlined where the main categorization is by: Mode (air, water, etc.), Function (line-haul, terminal), Geographic characteristics (urban, inter-city, international, e.g.), and Performance (safety, efficiency, speed). These inferences for cost-benefit analysis are suggested and the relevance of the growing importance of urban affairs in transportation planning is indicated. Finally, some of the consequences of the ambiguity of inputs and outputs in social programs are alluded to.

FP3.3 *The Northeast Corridor: A Comprehensive Systems Analysis, ROBERT A. NELSON, *Federal Railroad Administration, Washington, D.C.*

The Northeast Corridor Transportation Project is an effort to establish an analytical structure and a network simulation which will make it possible to predict the usefulness of a given transporation system in the Northeast Corridor. The paper points out both the philosophical and the technical issues involved with a project of this scope and complexity. The following are illustrative of

the difficulty of the analysis and the evaluation: 1. *The grain of the analysis.* The Corridor Project could not simulate the whole transportation system of the Corridor, nor could it get down to the household, the firm, or to detailed land use. 2. *The impact of the rest of the world on the Corridor and the impact of the Corridor on the rest of the world.* The Corridor is far from a closed system, yet the analysis cannot be detailed beyond the bounds of the Corridor. 3. *Interfacing with urban systems.* Intercity systems must interface with urban systems. Plans for urban systems are, however, quite uncertain and we cannot carry out analysis to the urban systems level. 4. *The economic objectives of the Corridor,* communities in the Corridor, regions adjacent to the Corridor, and the objectives of the Federal government. These are far from being known nor are they stable. 5. *The market cannot provide final answers on resource use,* yet government has not developed a way of establishing priorities.

FP4.1 *Pen Aids Optimization Model, KENNETH E. SHANK, *Raytheon Company, Space and Information Systems Division, Sudbury, Massachusetts.*

Contractual and related in-house development efforts in reentry systems has led to the requirement for a model that would permit evaluating the effectiveness of penetration aids; specifically penetration aids that enhance the survival of an IC/IRBM offensive force penetrating an ABM defense system under varying offense/defense engagement procedures. In view of this requirement, an in-house development effort was initiated to provide a computer simulation that was sufficiently general to permit assessing R/V survival probabilities and yet specific to the extent that spacing requirements for the reentering bodies could be established. The simulation was developed making full use of Raytheon's time share computer facilities and subsequently compiled for batch processing on an IBM 7044/7094. The simulation as it now exists provides for establishing jammer power requirements to achieve a desired probability of survival for a one-on-one or multiple engagement or conversely, given a fixed penetration aid capability evaluating the single or multiple R/V survival probabilities. Inputs to the simulation include defense characteristics such as radar/interceptor locations and performance parameters, offense characteristics such as launch/impact points, trajectory information, and penetration aid capabilities. Outputs from the program include jamming power requirements, decoy/jammer spacing requirements for selected probabilities of R/V survival, or R/V kill probabilities when pen aid requirements are fixed.

FP4.2 *Evaluating Subsystems for the Defense of a Strike Aircraft, J. A. BOOSE, *International Business Machines Corporation, Federal Systems Division, Electronics Systems Center, Oswego, New York 13827.*

An analysis was done to determine the worth of two threat sensing subsystems to an aircraft while penetrating a defended area. The two subsystems were considered as both competitive and complementary. The question of the necessity of either or both subsystems to the completion of a strike mission was investigated. The aircraft penetration was simulated over three flight paths at three altitudes and velocities by a computer program. The equipments were operationally modeled in an environment which included considerations of the effect of aircraft

maneuvers, weather and defense densities upon various configurations of self-defense subsystems. The simulation resulted in a set of estimates of the probabilities of successful mission accomplishment under a variety of circumstances.

FP4.3 *Defense Penetration Systems Optimization, JOHN E. PETRUCCI, JR., *Attack and Reconnaissance Section, Operations Analysis Dept., Grumman Aircraft Engineering Corporation, Bethpage, New York 11714.*

This paper addresses the general problem of optimizing defense penetration systems using non-linear programming techniques. In particular, the generalized Lagrangian multiplier technique is used. This technique retains most of the advantages of the classical method, and introduces advantages of its own. To demonstrate the utility of the theory, a defense penetration problem is studied in its simplest form. As an example, the problem of maximizing aircraft survivability while penetrating a surface-to-air missile (SAM) site defense is studied. To evaluate the effect of the SAM and the aircraft performance on successful penetration, a geometric model is developed. Through the exercise of the model, the original military problem is transformed to an optimization problem. The new problem formulation is solvable using a modification of classical Lagrangian optimization theory. Aircraft survivability is maximized, while constrained by the amount of resources allocated for a particular penetration mission. Relationships are developed to represent the function to be maximized, as well as the constraining functions. An algorithm is developed to implement the solution procedure. One result of this work is that the problem of optimizing military systems can be studied using non-linear programming techniques.

FP4.4 *An Aircraft Squadron Performance Effectiveness Model, LAWRENCE A. FEIDELMAN, *AUERBACH Corporation, 121 North Broad Street, Philadelphia, Pennsylvania 19107,* and LEO ROGIN, *Naval Air Development Center, Johnsville, Warminster, Pa.*

In the day-to-day operation of an aircraft squadron, two basic activities occur: flying of missions and maintenance of aircraft. Any model which attempts to simulate a squadron's operation and measure its performance in terms of aircraft availability and mission success must consider carefully the effects and interactions of these two activities. In addition, it should be realized that the subsystems of the various aircraft may fail while on a mission or may not be totally repaired when the aircraft is required for a new mission. The model must thus consider the case where some subsystems are inoperative which may result in degraded mission performance. The SPEAR (Squadron Performance Effectiveness Analytic Representation) program was developed for the Naval Air Development Center to be used for aircraft system and maintenance facility evaluation and is written in 3200 FORTRAN. SPEAR uses a combination of analytic and and simulation techniques to represent the squadron status while its aircraft are participating on missions and undergoing repair. Analytic techniques are used to calculate the condition and location of the aircraft and maintenance queues by means of probability distributions. Simulation techniques are used to specify the activities that occur based on the squadron flying schedule and aircraft re-

supply timing. The inputs to model are aircraft system descriptions by equipment, equipment reliability and maintainability statistics, mission profiles and a description of the aircraft maintenance facility. The basic program outputs are aircraft availability by mission, aircraft mission performance in degraded as well as normal mode and maintenance facility queues.

FP5.1 *Evaluation of Educational Programs: A Systems Approach, MARTIN I. TAFT, *Associate Professor of Engineering, California State College at Los Angeles, Los Angeles, California 90024,* and ARNOLD REISMAN, *Associate Professor of Operations Research, Case Western Reserve University, Cleveland, Ohio 44106.*

Although a dialogue has been initiated, within recent years, between operations analysts and school administrators, most of the operations research work in education has addressed itself to the analysis and/or implementation of alternative programs and policies assuming that the value system of the institution is known. This paper is an attempt at bringing operations research methods to aid in the setting of goals, objectives, the utilities, and the criteria of evaluation of educational programs. It represents an integration of concepts from the utility theory of economics; criterion function theory from engineering design; decision and subjective probability theories; and the Delphi methodology for arriving at a consensus of opinions for the purpose of identifying and evaluating the goals, the objectives and their attainment within various educational establishments and/or programs. The methodology is aided by Fortran II and Fortran IV computer programs; the latter was designed for use in a time-sharing mode.

FP5.2 *An Analysis of Teacher Supply and Demand in California, ANTON S. MORTON, *Arthur D. Little, Inc., Cambridge, Massachusetts 02140.*

A model of input to and output from teaching in California showed the effects of the Teacher Preparatory Institutions (TPI's), the schools, and teachers themselves. The model was based on a reconnaissance, questionnaires addressed to a 5% sample of teachers and their administrators, interviews at the TPI's, and questionnaires on career choice filled out by college students. By collating information from these sources, we estimated the extent of future shortages at the elementary and secondary levels, and adduced reasons for them. We recommended to the California State Board of Education a series of actions on the part of various responsible agencies to help relieve the expected teacher shortage. To bring back into teaching those who had left was shown as critical. Setting up a management information system on the status and whereabouts of credentialled teachers was discussed in detail as a way to accomplish this.

FP5.3 *On Attempting to Relate the Inputs and Outputs of Institutions of Higher Education, RICHARD J. O'BRIEN, and JUDITH ZINTER, *U.S. Office of Education, Washington, D.C. 20202.*

This paper is concerned with the research task of relating inputs and outputs of institutions of higher education. Output measures such as the number of PhD's produced, percent of the senior class expecting to continue in graduate school and

a subjectively derived rating scale are considered. Input variables describing the ability of the incoming student and the nature of the college environment which he experiences are used. These variables include Scholastic Aptitude Test scores, expenditures per student, student teacher ratios, enrollment size and percent of faculty with PhD's. The study is approached with the point of view of determining the adequacy of the selected output measures, both in their predictability and in their differentiation among institutions of higher education. This is accomplished by estimating the degree of relationship among variables and in studying the outliers of the regression equations. Empirical results are given on the effects of the interrelationship of the input variables.

FP6.1 A Mathematical Model for the Optimization of A Generalized Waste Management System, LOREN E. ANDERSON, *The Boeing Company, Commercial Airplane Division, P. O. Box 707, Renton, Washington 98055.*

The purpose of this paper is to illustrate a parametric, linear programming solution methodology for a specialized, multi-commodity network. Specifically, the important problem of transporting and treating all waste (solid, liquid, gas) generated in a typical communal waste system is examined and a method developed which optimizes the overall system operation, i.e., ships and processes all waste generated at the source, through intermediate treatment plants if required, to the final sinks subject to arc and activity capacities, and does so at a minimum cost. The main interest of this analysis is the treatment of the multi-commodity (solid, liquid, gas) situation. By utilizing the inherent system structure, the multi-commodity flow is reduced to a common commodity and directed along appropriate routes by incorporating fixed-ratio flow separator arcs. Utilizing this arc divider set, a finite algorithm is developed and substantiated which uses a modified "out-of-kilter" network solution technique to very efficiently optimize the overall system.

FP6.2 Forecasting for Production Planning, STEVEN S. LAZARUS, *College of Business Administration, University of Rochester.*

This study concerns the application of forecasting models to a production planning problem. It is desired that a monthly forecast be prepared for net orders received, that is new orders received minus cancellations of previous orders. The performance of zero, one and two degree equation models, both with and without seasonal factors, is measured for eight products. The best models are selected to forecast net monthly orders received for the next year. Model stability is also analyzed. A qualitative analysis is made of additional causal factors.

FP6.3 An Algorithm for the Planning and Optimization of a Rough Turning Operation, P. BRUCE BERRA, *Department of Industrial Engineering Syracuse University, Syracuse, New York 13210,* and MOSHE M. BARASH, *School of Industrial Engineering, Purdue University, Lafayette, Indiana 47907.*

Information on the component to be manufactured is placed in matrix form for acceptance by the computerized algorithm. The algorithm generates a number of matrices that represent the component at various stages of completion in the manufacturing process and a matrix that indicates the required operations for each

section of the component. In its present form, only the matrix that provides information on the component for the rough cutting operations is utilized by succeeding portions of the algorithm. After selection of raw material characteristics, machine parameters and tooling, the rough turning operations are planned and optimized with the criterion of minimum machine time. A detailed flow diagram of the algorithm and an example for the rough turning of a steel shaft are presented.

FP6.4 A Cost Effectiveness Model of Hospital Pharmacy Inventory and Drug Utilization Systems, PAUL M. WOOD, *Travelers Research Center, Inc., 250 Constitution Plaza, Hartford, Connecticut.*

The utilization of drugs for prevention, diagnosis, and treatment is a major factor in the provision of health care. The provision of a satisfactory variety of drugs with a specified probability of availability, together with the appropriateness of utilization of individual drugs, are prime elements in the effectiveness with which health care is delivered. Different levels of effectiveness are possible and do indeed exist. Alternative means of achieving different levels can be generated. Comparison of promising alternatives and their associated costs provides a basis for more informed decision-making relative to achieving specified and defined levels of system effectiveness. The theoretical basis of a hospital pharmacy inventory and utilization model is presented. Elements and levels of effectivensss are discussed as are alternative means of achieving different effectiveness levels and their associated costs. An application of the model is discussed.

FP7.1 A Practical Algorithm for Finding Solutions to the Traveling Salesman Problem, RICHARD E. OBERUC, *Uncle Ben's, Inc., Houston, Texas.*

In spite of the seeming simplicity of this problem, the lack of a practical approach for solving the TSP with more than 50 nodes has irked researchers for some time. A new algorithm has been designed which has found optimal solutions to five problems defined in the literature, ranging from 20 to 57 nodes. In order to test the power of the algorithm, three new problems were defined: 75 node, 86 node and 100 node. Solutions to these problems are presented in hopes that they can provide a basis of comparison for further investigations of large node problems. This algorithm is compared to a half dozen other techniques regarding ability to find optimal solutions and the required computer time to obtain an optimal solution for the five well-known problems. It is demonstrated that not only does this algorithm consistently produce optimal results but it does so in less time than any other algorithm investigated. A Fortran IV computer program for this algorithm exists which requires input of only the number of nodes involved and the internode distances.

FP7.2 Pathology and Therapy for Traveling Salesman Algorithms, M. BELLMORE, *The Johns Hopkins University, Baltimore, Maryland 21218,* and J. C. MALONE, *The Bell Telephone Laboratories, Holmdel, New Jersey 07733.*

As the result of a tremendous volume of research over the past 22 years, many algorithms for an exact solution of the traveling salesman problem have been developed. Even the best of these algorithms is subject to pathological behavior for broad classes of problems of practical interest. A theory is established which explains the performance of many of these algorithms in practice. This theory is then used as a basis for modification of several of these algorithms to improve their performance. A hybrid algorithm is finally evolved which combines powerful heuristic techniques and a tightly bounded implicit enumeration scheme into an algorithm which is largely immune to the pathologies which afflict existing algorithms. Computational results for this algorithm on classical problems are presented.

FP7.3 A Method of Solving Traveling Salesman Problem, D. K. GUHA, *The Port of New York Authority, 111 Eighth Avenue, New York, New York 10011.*

An assignment problem with very large diagonal elements is solved initially. If the optimal solution consists of a number of subcycles of the cities, the algorithm picks out from the final matrix exits from each subcycle with minimum costs. A path is then sought along these exits from subcycle to subcycle so that a single cycle is produced. If a cycle is not obtained along these minimum exits, a series of iteration will produce a cycle with a length which is the smallest of all such paths constructed. Let us denote this by v_0. The exits of some subcycles are not minimum in this cycle. Every exit out of each of these subcycles with a value lower than that of the exit used in the cycle is picked out. These are the branches of the problem. Along each of these branches the resulting traveling salesman problem is solved by repeating the above method. v_0 is revised as soon as a feasible solution along some branch with a lower value is obtained. On examining all of these branches optimal solution is obtained.

Society Affairs

MINUTES OF THE ORSA COUNCIL MEETING

The thirty-third Meeting of the Council of the Operations Research Society of America convened on 30 April 1968, in the St. Francis Hotel, San Francisco, California, with John E. Walsh, President, presiding, and reconvened after the Business Meeting on 1 May 1968, with President Joseph H. Engel presiding. The following items from the Council Meeting are reported. (Complete minutes can be obtained from the Secretary of ORSA.)

FUTURE ORSA MEETINGS

No.	Dates	Location	
34	November 6–8, 1968	Philadelphia	LEO ROGIN *Air Warfare Research Dept.* *NADC* *Johnsville, Pa. 18974*
35	June 17–20, 1969	Denver	GEORGE W. MORGENTHALER *The Martin Company* *Box 179* *Denver, Colorado 80201*
36	November 10–12, 1969	Miami, Fla.	MICHAEL E. THOMAS *Industrial & Systems Eng. Dept.* *University of Florida* *Gainesville, Florida 32601*
37	April 20–22, 1970	Washington, D. C.	HOWARD BERGER *OASD(Sa)—The Pentagon* *Washington, D. C. 20301*
38	Fall 1970	Ann Arbor	RICHARD C. JELINEK *Industrial Engineering Dept.* *University of Michigan* *Ann Arbor, Michigan 48104*
39	Spring 1971	Dallas	RONALD L. GUE *Computer Sciences Center* *Southern Methodist Univ.* *Dallas, Texas 75222*
40	Fall 1971	Los Angeles	GERHARD L. HOLLANDER *P. O. Box 2276* *Fullerton, California 92633*
41	Spring 1972	New Orleans	JOSEPH L. BALINTFY *Graduate School of Business* *Tulane University* *New Orleans, La. 70118*

MEMBERSHIP COMMITTEE

Of 140 applicants for a transfer from Associate Member to Member, 90 were approved. The names are indicated on page B-316.

PUBLICATIONS COMMITTEE

Hugh Miser was approved as the new Editor of *Operations Research*. A group at the University of Wisconsin in Milwaukee was authorized to undertake the

preparation of a 15-year cumulative index for *Operations Research*. Hugh Bradley was approved as the new Editor of *International Abstracts in Operations Research*, effective July 1, 1968.

SECTIONS COMMITTEE

New student sections at Texas A&M and the U.S. Naval Postgraduate School were approved. It was agreed that the Western Section should be split up. The smaller sections and mechanisms for doing this were discussed.

TREASURER:

Thomas E. Oberbeck discussed the financial status of the Society indicating that expenses may be growing more rapidly than income. However, the Society does not appear to be in imminent financial danger.

IFORS

John Magee reported that a delegation of 100 ORSA members has been invited to attend the 1969 International Conference to be held in Venice, Italy, June 23–27, 1969.

EDUCATION COMMITTEE

Jack Borsting reported that the Visiting Lectureship Program is progressing successfully and that a grant from NSF for partial support of this program has been received. The Education Committee was authorized by the Council to prepare a brochure entitled "Careers in Operations Research."

LIAISON WITH OTHER SOCIETIES

The Council agreed that liaison with other societies is desirable. Gordon Shellard was designated as liaison with the Society of Actuaries, and Robert E. Machol was reaffirmed as liaison with the Systems Science and Cybernetics Group of the IEEE.

1968–69 COMMITTEES

The following committee chairmen were appointed by the President:

Membership Committee:	Ezra Krendel
Publications Committee:	Robert Oliver
Education Committee:	Jack Borsting
Nominating Committee:	Alfred Blumstein
Lanchester Prize Committee:	George Shortley
Meetings Committee:	Allan Harbaugh
Sections Committee:	William Nemerever
Long Range Planning Committee:	Thomas Oberbeck
Representative to CBMS:	Alex Mood
Representative to NRC:	Hugh Miser
Representatives to AAAS:	W. Edward Cushen
	Ellis Johnson
	Bernard Watson (Alternate)

ROBERT E. MACHOL
Secretary

NEW MEMBERS—83d National Meeting

The Membership Committee reported its nominees for full membership in the Society. The following were elected by the Council as new Members:

BALAS, EGON
BARTLETT, THOMAS E.
BELKIN, JACOB
BELLMORE, DR. MANDELL
BELLIS, WESLEY R.
BESKIND, BERNARD L.
BODO, JOSEPH
BOLL, DR. CHARLES H.
BRAD, DR. NIEL A.
BROSH, ISRAEL
BROWN, CARL A.
BUCHSBAUM, DR. LARRY
BUCKNER, GEORGE A.
CARSWELL, WILLIAM A.
CHANG, YU SANG
CLARK, JOHN D.
COBB, LAWRENCE R.
CONNOLLY, JAMES P.
COPPEDGE, THOMAS N., JR.
CORBETT, HOWARD R., JR.
CUMMINS, P. Z., II
CURRY, DAVID A.
DELFICO, JOSEPH F.
DEMING, DR. W. EDWARDS
DESSAU, ERLING
DIXON, THOMAS D.
EBY, CHARLES L.
EDGE, CHARLES G
ESHELMAN, CHARLES R.
FENSTERSTOCK, ALBERT
FERGUSON, ALLEN R.
FISH, FRANK
FISHER, DR. GORDON P.
FLANNAGAN, JOHN C.
FORREST, DR. ROBERT N.
FREEMAN, DR. JOHN R.
FRISCH, FRANZ A. P.
GILLIAM, RONALD R.
GOLDSTEIN, JACK
GOODFRIEND, RICHARD D.
GOSWICK, THOMAS E.
GRANT, DAVID T.
HAMILTON, FRANK P.
HARRIS, DR. CARL M.
HARRIS, DR. GEORGE H.
HELD, DR. MICHAEL
HUBBARD, HERBERT B.
HURST, DR. ERNEST G., JR.
IGNALL, DR. EDWARD J.
JACKSON, HERBERT
KAMLER, EMORY N.
KIBLER, DEWEY E.
KISIEL, DR. CHESTER C.
KRAKOWSKI, DR. MARTIN
LANGSFORD, GUY L.
LENHART, CHARLES D.
LENNON, ROBERT A.
MAYER, DR. RICHARD A.
MCMAHAN, RICHARD H., JR.
MCQUIE, ROBERT
MILCH, DR. PAUL R.
MILLER, DR. RALPH L.
MORRISON, RALPH W.
MOSSBARGER, JOHN W.
MURPHY, DR. ALLAN H.
NAPOLI, JOSEPH C.
NELSON, DR. FRANK M.
NEMESVARY, LASZLO D.
O'CONNOR, ARTHUR D.
OLMSTEAD, BLAIR E.
PIERSKALLA, KENNETH D.
REYNOLDS, WILLIAM E., SR.
RIGG, EDWARD H.
RODGERS, EDWARD G.
ROSEMAN, HERBERT B.
ROTH, LARRY T.
SCHKADE, DR. LAWRENCE L.
SCHWEITZER, DR. PAUL L.
SIMPSON, PETER
SMITH, DR. KEITH V.
SRYGLEY, JAMES G.
STONE, ANDREW W
VUILLEMOT, FLOYD L.
WATSON, JAMES R.

WEBB, N. CONANT, JR.
WEISS, ARMAND B.
WHELAN, DR. WILLIAM J.
WILLIAMSON, WILLIAM G.
WOLMAN, ERIC
WOOD, DR. KARL D.

PRESIDENT JOHN E. WALSH'S REPORT (RETIRING)

Several things of note have occurred since our Business Meeting in 1967. First, a joint meeting was held with the American Institute of Aeronautics and Astronautics (AIAA) on March 18–20, 1968, in Washington, D.C. This forum, the first of its kind for ORSA, was devoted to Systems Analysis for Social Change. A suggestion by Vice President Hubert H. Humphrey, that systems analysis methods developed for the aerospace industry be carried over to other areas of public interest, motivated the development of this forum. Dr. L. Eugene Root was General Chairman of this Forum, and the ORSA President was Co-Chairman:

Second, a Visiting Lecturship Series has been initiated for the field of Operations Research. Visits to many universities who do not have established operations research programs were made this spring. These lecturships will be partially supported by the National Science Foundation starting next fall.

Third, two new Technical Sections have been formed. These are the Space Sciences Section and the Health Applications Section.

Fourth, it seems that ORSA, and the field of operations research, now has the status of being established in the United States. Establishment has, of course, been the primary goal of the Society. In recognition of this attainment, the Long Range Planning Committee is coping with the problem of identifying other goals for ORSA.

Finally, with deep regret and sorrow, the passing on of Dr. George E. Kimball is noted. He was a former President of ORSA and one of its most distinguished members.

Committee Appointments

Membership Committee

Ezra Krendel, Chairman
Bill Cummings
Loring Mitten
Burnham Gould
William Marcuse
Keith McRoberts

Publication Committee

Robert Oliver, Chairman
Joe McCloskey
James Banton
Kenneth Soderstrom
John Locke
Jack Moshman
Eugene Lawler

Sections Committee

William J. Nemerever, Chairman
Stephen Pollock
Pat Robinson
Wilton Whisler
Walter Helly
Joe Noah

Lanchester Prize Committee

George Shortley, Chairman
John Magee
John Walsh

Nominating Committee

Alfred Blumstein, Chairman

Long Range Planning Committee

Thomas E. Oberbeck, Chairman
Grace Kelleher
Clayton Thomas
Georges Brigham
Raoul J. Freeman
George Chacko
George W. Morgenthaler

Education Committee

Jack Borsting, Chairman
David Schrady
Mike Thomas
Seth Bonder
Leon White
M. E. Bell
George Burch

Meetings Committee

Allan Harbaugh, Chairman
Alan Rowe
Martin Aronoff
Anton S. Morton
Armand B. Weiss

Representatives to AAAS

W. Edward Cushen
Ellis Johnson
Bernard B. Watson (Alternate)

Representative to CBMS

Alex Mood

Representative to NRC

Hugh Miser

News and Announcements

THE PROFESSIONAL SOCIETY AND ITS PUBLIC RESPONSIBILITY

The luncheon meeting of the Society on 8 November 1968 will be an occasion for discussion of the public responsibility of contemporary professional societies. The discussion will be initiated with a luncheon address by Mr. Fred S. Hoffman, Assistant Director, Bureau of the Budget, on the subject, "Analysis for Public Policy." The considerable experience that the American Medical Association has had in discharging its public responsibility will be discussed by Mr. Darrell Coover, Assistant Director of the Field Service Division. Mr. Coover who was until recently AMA's Legislative Representative on Capitol Hill, has chosen as the title of his panel presentation: "How Do You Speak to Congress?" Further background for this discussion is provided by the Report of the Long Range Planning Committee of ORSA which appears on page 322 of this issue of the *Bulletin*. Dr. Clinton P. Ancker, Jr., who served as Chairman of the Long Range Planning Committee (1967–1968) which prepared the Report will speak on behalf of the concepts advanced by the Committee. There will also be presentations by representatives of other professional societies which have pursued programs to serve the public interest along lines such as those identified in the Report. The subject will then be opened to further discussion by the membership to provide guidance to the present Long Range Planning Committee. Dr. Thomas E. Oberbeck, presently Chairman of the Committee, will chair the session.

AAS/ORSA JOINT NATIONAL MEETING IN DENVER IN 1969

Planning Challenges of the 70's in Space and the Public Domain will be the theme of the Joint ORSA/American Astronautical Society National Meeting will be held June 17–20, 1969 at the Brown Palace Hotel in Denver, Colorado. This will be the 15th annual meeting of the American Astronautical Society and the 35th National ORSA meeting.

Why a theme focusing on such broad national problems? The astronautical community and the operations research community have each passed their 15th birthdays and each has peculiar challenges for further growth.

The nation's leaders, reflecting the people's views, have made it clear that space exploration will no longer be strongly supported unless space *exploitation* is forthcoming. It will be necessary for the astronautical community to acquaint itself with the problems of man on Earth and to seek to apply space technology skills to their solutions. The AAS must aim at this objective.

The operations researcher has been told often of late that his art has concerned itself too much with technique and not enough with the problems as they lie before man. His employment of measures of merit has not always included the cultural, the aesthetic, and the ultimate relation to broader objectives of society. He needs reorientation and focusing on the great projects of man in better planning of cities, resource utilization, and social programs, as well as the space program and its potential.

This joint meeting is an opportunity to survey and debate these problems lying

before man and to depart more boldly in the attempts at solution. Overall systems models and studies of the planned utilization of the Earth as a fulfilling habitat for man must be a goal of the next years if man is not to lose his chance for a golden age of culture and creativity.

The present planning of the meeting is centered around two main hotel auditoria. In the first auditorium theme sessions featuring invited and contributed papers by national authorities in space sciences, spacecraft and launch vehicle design, and space mission analysis will be conducted projecting the future course of the space program. Sessions will include: Future Earth Orbital Science Missions; Future Lunar Missions; Automatic Planetary Probes; Future Manned Planetary Missions; Large Space Stations, Space Logistics, and Rescue; Search for Extra-Terrestrial Life and Exobiology.

In the second auditorium theme sessions will be held on the major planning challenges of the 70's in the Public Domain areas. These will include: Management of Populations; Management of Power and Energy Resources; Management and Expansion of Food and Forest Resources; Management of Mineral Resources; Management and Expansion of Water Resources; Management of Wastes and Pollutants; Management of Land Use, Urban Planning, and Housing; Surface Transportation and Distribution Systems. Again, many of the papers in these sessions will be invited papers and will feature world authorities in these fields. Contributed papers will also be welcomed and reviewed for possible inclusion in the theme sessions.

Specialist sessions in both the astronautical disciplines and the OR disciplines will be held concurrently with the large theme sessions. In the astronautical field, the specialist sessions will include: Astrophysics, Advanced Propulsion, Advanced Aerospace Structures, Spacecraft Design, Space Electronics, Guidance and Control, etc. In the OR field, specialist sessions will be held in the following technical areas: Inventory Models, Scheduling Models, Queuing Theories, Programming Models, etc. Contributed papers will be welcomed for all of these specialist sessions, although it is expected that key invited state-of-the-art papers will be presented in most sessions.

Each of the Sections of ORSA such as the Transportation Sciences Section, the Health Application Section, Cost Effectiveness Section, etc. will be assigned specific sessions in which invited and submitted papers may be presented. Naturally, because of the close tie between the Space Sciences Section of ORSA and the objectives of the American Astronautical Society, the Space Sciences Section is expected to play even a more comprehensive role in the total structure of the program.

A committee has also been formed to solicit exhibits in a number of areas such as: Astronautical Hardware and Mission exhibits, Astronautical and Systems Analysis book exhibits, Computer and Software exhibits, and Sensor and Space Experiment exhibits. Exhibits will be welcomed by aerospace, electronics, and computer companies, book companies, government agencies, and university research organizations.

In order to achieve the most authoritative contributions in a number of technical areas within the overall program, several other national Societies have been invited

and have accepted roles as participating societies in the meeting. These include: the American Institute of Biological Sciences for the space biological areas and the pollution areas; the Society of Logistics Engineers for the space logistics and transportation areas; the Rocky Mountain Section of the American Institute of Aeronautics and Astronautics for the overall astronautical specialty areas; the Institute of Management Sciences for overall management areas; and the Working Group of Extraterrestrial Resources.

The General Program Manager for the meeting is Dr. George W. Morgenthaler, Director of Research and Development, Martin Marietta Corporation, Mail No. 1600, P. O. Box 179, Denver, Colorado 80201—Tel. (AC 303) 794–5211, Ext. 4575.

The meeting committee urges all members of ORSA to plan *now* for the participation of their organization and colleagues in this ambitious and significant technical exchange. Specifically, we urge you to contact the General Program Chairman with suggested papers, company exhibits, and any other contribution which you feel may be made toward the success of the meeting. Paper abstracts should be sent to the ORSA Technical Program Chairman, Mr. Jack G. Shaffer, Gates Aviation Co., 444 Stapleton International Airport, Denver, Colorado, 80207, on or before January 1, 1969.

36th NATIONAL ORSA MEETING

The 36th National Meeting will be held at the Americana Hotel in Miami Beach, Florida, on November 10, 11 and 12 of 1969. The theme for the meeting will be "Operations Research in the Development of Emerging Countries." Two types of sessions will be held and will include both invited and contributed papers. Several simultaneous sessions will also be conducted. The papers in the simultaneous sessions will be presented several times during the period for which they are scheduled. Inquiries regarding the program should be addressed to Dr. Salah Elmaghraby, Department of Industrial Engineering, North Carolina State University, Raleigh, North Carolina. Inquiries on other matters should be addressed to Dr. M. E. Thomas, Department of Industrial and Systems Engineering, University of Florida, Gainesville, Florida, 32601.

EDUCATION NEWS

The Committee will regularly publish information concerning degree programs in Operations Research. The following changes in programs listed in an earlier Committee report (*Bulletin*, Vol. 15, Sup. 2) are reported. News of new programs or significant changes in existing programs should be sent to Prof. J. R. Borsting, Chairman, ORSA Education Committee, Naval Postgraduate School, Monterey, California 93940.

Stanford University

The Department of Operations Research became the newest department in the School of Engineering at Stanford, receiving departmental status beginning with the 1967–68 academic year. Stanford has had an interdepartmental Operations Research program since 1962. From a student point of view, the interdepartmental program was indistinguishable from a department. However, departmental status makes the Operations Research faculty a more cohesive group and simplifies ad-

ministration. Prof. Gerald J. Lieberman is the executive head of the new department.

Case Western Reserve University

With the federation of Case Institute of Technology and Western Reserve University on 1 July 1967, the Department of Operations Research in the School of Management of Case Western Reserve University was established. The former Case Operations Research Group forms the nucleus of the new department. Chairman of the department is Prof. Burton V. Dean.

THE LONG RANGE PLANNING COMMITTEE

At the May 1967 National Meeting of the Operations Research Society of America, the Council of the Society decided to establish a Committee on Long Range Planning. The President of the Society immediately selected a chairman and by mutual agreement between them the other members were nominated, solicited and appointed. No definitive charter was issued at that time.

Subsequently, the committee met collectively several times and also conferred individually on what the purview and procedures of the committee should be. The President was kept advised. Concurrently, all members of the Council, all chairmen of standing committees and other senior members of the Society (known to be interested in the subject) were queried by mail as to their views on what the committee should do and what were appropriate topics for consideration. About one-half of the people contacted responded.

As a result of all this activity, the committee went to the Council at the November 1967 National Meeting of the Society and obtained approval of a proposal that the most immediate and meaningful way that it could operate would be to select one or more specific questions from the set generated by the preceding activities and discuss these as fully as time would permit. Any and all activities (actual or possible) of the Society were considered as candidates for examination. Of course, any questions known to be under active consideration elsewhere in the Society would not be entertained. It was fully understood that the committee members were busy people and thus complete and exhaustive staff work would be impossible. It was further agreed that a report would be submitted to the Council at the May 1968 National Meeting. This report is attached.

Additionally, it was agreed that a notice would be published in the Journal inviting any member of the Society to contribute his thoughts on this subject. The notice was published in the January-February 1968 issue of the Journal. Since this has just come out no response has been received as yet.

Finally, the appendix to the report contains an edited and compiled list of all the questions (except those considered in the report) proposed to date from all sources. This list could serve as a starting point for any future activities of the committee.

The Committee has considered two distinct but not unrelated questions viz: (1) public responsibility and (2) ORSA membership: growth, criteria and composition. Many other questions were proposed (see the Appendix) but these seemed timely, important and within our capability to examine. The discussions which follow are not exhaustive. They do represent our best thinking applied within the

time available. We hope they will trigger both a more thorough examination of these topics and most important of all—some action.

I. *PUBLIC RESPONSIBILITY*

Does the Operations Research Society of America as a distinct professional group, have a public responsibility? By this we mean, should the Society take a public stand on issues which lie within the professional competence of the membership?

Anyone who belongs to one or more professional societies must be aware of the fact that this question is being asked more insistently every day. As we are being overwhelmed by the problems of air pollution, highway safety, urban transportation, decaying cities, law enforcement and many more, the cry is being heard "What can science and technology do for us? You created these problems (at least in large measure), help us solve them." It is simple to raise the plea; it is not so simple to respond to it.

There is nothing in either the Articles of Incorporation or the Constitution and Bylaws of the Society which bears directly* on this question. Neither instrument excludes the possibility of public service, they simply ignore it. Most scientific and technical professional people work in government (including military), private industry, nonprofit institutions or in colleges and universities. When controversial public questions with a strong technical content arise, few professionals indeed are willing to make public statements. Generally, the few who do are from the academic community or from the senior members of the profession who either have or are about to retire. There is nothing wrong with these people speaking up, what is wrong is that the remainder are silent.

This situation clearly produces an unbalanced and muffled response. The reasons for the silence of the majority are obvious, and can be summed up as either a real or an imagined conflict of interest, namely; the parochial interest of the professional's employer versus the professional judgment of the employee. This is a difficult position and is not unique to operations research. In particular, all branches of engineering and science seem to be especially plagued by the problem.

We submit that the profession does have an obligation to the public and that it is not meeting it or at best is only doing so half-heartedly. There appears to be only one way out of this dilemma and that is through the Society. No other mechanism we know of is presently available and no other is even on the horizon.

This use of a professional society is not entirely without precedent. Although apathy generally is the rule, it is not completely the case. For example, the American Society of Mechanical Engineers issues boiler codes which are generally used in the industry and also recently took a stand on converting to the metric system. However, although there is a mounting pressure in professional organizations (as opposed to trade groups and others) to speak up, timidity and uncertainty are still predominant.

* The Third Article of Incorporation and Article II of the Constitution both state as goals ". . . the establishment and maintenance of professional standards of competence for work known as operations research" . . . and ". . . the encouragement and development of students of operation research." These are perhaps peripheral issues, related to public responsibility.

The Society can serve the public interest and at the same time can protect its members from possible undue retaliation by appropriate actions on its part. The major question involved here is, should the Society take a public posture on issues where substantial segments of the membership may be in disagreement? We can only answer that this is our national way of life. To say no to this question is to relegate the Society either to the graveyard of discarded and useless mechanisms or, at best, to allow it to sink into a relatively quiescent state. Surely, we cannot abrogate our responsibilities by pleading lack of unanimity. This is, in fact, to allow the few to exercise a tyranny over the many. Another way to put this is, if scientists refuse to assess the impact of their science on society, who is to do it—only politicians or selfishly motivated special interest groups? Therefore, the real question is not should the many be heard but how can this be accomplished?

We believe the answer to this question lies in the Council. They are, in fact, our duly elected representatives. It is their responsibility to act for the membership in all proper matters. If, occasionally, they should not be responsive to the members' desires this fact will soon be made clear to them. Thus it seems to us that the Council may take such actions as it deems appropriate to make the voice of the profession heard on those essential issues of the day which require attention.

Before we tackle the problem of what issues are appropriate, let us address the question of how our voice can be heard. Several possibilities are immediately apparent. First of all, the Society can prepare and deliver testimony to Congress and other duly constituted legal bodies, either by invitation or at its own request. This is perhaps the method with the greatest public exposure. Another method is to offer press releases or hold press conferences discussing relevant issues. Still another mechanism is to appoint committees to advise and counsel government agencies on their many problems. This latter may perhaps be the most useful procedure and might encompass many activities ranging from broad policy advice to very direct evaluation of specific programs. There is some precedent for all these approaches, but generally they have been used most effectively by special interest groups and trade groups with rather obvious axes to grind. Perhaps this is one reason why professional and scientific organizations have tended to avoid the arena, namely, for fear of being tabbed "nonprofessional" or "political". This is, of course, a pitfall and is one which must be vigorously guarded against (a Council responsibility) but is not an excuse for inaction.

The next problem is how to proceed. Again several possibilities suggest themselves. A good vehicle might be the technical sections. For example, on issues involving cost effectiveness the Council might request a fully staffed report from the C/E Section. Or, if a military agency requested an advisory committee, the Military Applications Section might be asked to supply a panel of names and so on. In the latter case, no doubt, the Council would want to screen the names and issue a charter detailing (insofar as possible) policy guidance. If a question did not clearly come within the purview of a technical section then the Council might appoint a special ad hoc committee to deal with it.

All of this sounds as though it might entail a good deal of work and indeed it would. However, it is our belief that for such an obviously important and worthy cause a great many members would be willing to serve. In fact, such service would

rightly be deemed an honor. This might, in fact, be a good mechanism for involving many more of the members directly in the activities of the Society.

Let us now consider some specific activities in which the Society might undertake a role of public service. This brief list is not intended to be exclusive or exhaustive, it is merely illustrative.

The cost effectiveness of highway safety countermeasures.

The national transportation system viewed from the system standpoint.

The cost effectiveness of the national health system.

Qualification criteria for various grades of operations analysts in government service.

A role analogous to that of the Engineers Council for Professional Development in certifying engineering curricula at universities.

Advice to Federal military academies on course content in military OR curricula.

To summarize, although several questions need further examination (e.g. how can the Society protect the individuals involved and is a Constitutional Amendment required?), it is our opinion that the Society can and should undertake a public service function. The Council should act as the duly elected representatives of the membership in this role and has at its disposal numerous channels (e.g. Technical Sections) for selecting competent and effective agents. The need is great, the time to respond is now.

II. *ORSA MEMBERSHIP: GROWTH, CRITERIA AND COMPOSITION*

From the diverse suggestions submitted to the Long Range Planning Committee it is clear that the thought of "planning" arouses very different reactions in different individuals. One past president, for example, sees a challenge to apply operations research methods in a study of the future of operations research, starting with a consideration of long term objectives of the society, and evaluating possible society structures and actions as means of achieving those objectives. Another past president, however, sees in preoccupation with planning "an unwillingness to tolerate the ambiguity implicit in leaving the initiative and long-term future of ORSA with the individual members." In his concern with possible dangers of planning, he seems to see threats of a dictatorial minority, as he says "ORSA is a comfortable, evolving organization that leaves room for the initiative of the membership but does not require more than a member cares to contribute. I prefer this to a tightly run activity in the hands of a dominant central group." Curiously enough, still another senior member, who states "a preference for the democracy of science rather than the dictatorship of professionalism" and thus is also "anti-totalitarian," differs from the somewhat laissez-faire approach toward planning. He asks, rhetorically, "are we content to let OR . . . grow where it will or do we have an obligation to bring it to the attention of those who 'need' it (perhaps without realizing this)." Clearly his feeling is that "we" do have a responsibility—"we" as the society.

But both of these contrasting views have in common a great concern with "who we are." Are "we" to be a "comfortable, evolving" collection of members with "initiative," or a "tightly run activity in the hands of a dominant central group?" Are we to have the "democracy of science" or the "dictatorship of pro-

fessionalism?" These rather general questions raise some specific questions concerning our membership trends and policies. *What should be our criteria; how rapidly should the membership increase; to what extent should we have internal "grades" of members; to what extent should our membership capture the potential market;* etc. Each of these questions will be discussed after first examining some of the trends already evident in our membership and some ways of looking at our potential.

Trends in Membership Growth

A recent ORSA Bulletin (Vol. 15, Supplement 3, Fall 1967, pp. B-273) gives interesting data on ORSA members and subscribers. A portion of the data is summarized in the table below:

Year	Y	Members (E)	Total Membership* (M)
1952	0	73	73
1953	1	354	560
1954	2	439	892
1955	3	452	1203
1956	4	526	1508
1957	5	689	2009
1958	6	832	2330
1959	7	897	2640
1960	8	944	2944
1961	9	1021	3205
1962	10	1137	3583
1963	11	1316	3990
1964	12	1365	4159
1965	13	1590	4577
1966	14	1750	5128
1967	15	1897	5963

* Total Membership = Members + Associate Members + Student Associate Members

One possible indicator of our "democratic" tendencies might be the ratio of members to total membership, E/M. From the basic table one derives the following results:

Y: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

E/M: 100% 63% 49% 38% 35% 34% 36% 34% 32% 32% 32% 33% 33% 35% 34% 32%

One sees that after a fairly sharp decline to about 35% in the first four years of our society, about ⅓ of us have been in the "elite" group of members, with the value of E/M lying between 32% and 36% ever since 1957. Certainly there has been no pronounced trend in E/M of recent years.

One may turn then to M itself, and its relation to the "population at large" for evidence of trends. The Bulletin article remarks that through May 1966 the growth could be described by the line of regression $M = 344Y + 182$ to within 130 members, but observes:

"However, during the 1966–67 year the Society's growth was over double what one would expect from these trends: 835 members .... If lines of regression are

derived for the data including this 1967 point, one obtains M = 357Y + 117 . . . but (this relation fails) to predict the 1967 actual data by 491 members . . . , even though the other errors are within 242 members . . . ."

The Bulletin article then concludes with the statement:

"It will be interesting to see whether the linear trend continues, or whether the 1966–67 experience marks a new pattern of growth for the Society."

In this connection it is interesting to note that the "1966–67 experience" is not the earliest indication of a possible "new pattern of growth," for the last two years, or even three years, of membership data show some deviations from earlier experience. First of all, consider the revised regression line M = 357Y + 117. As noted above, the 1967 point lies well above this line. What is also suggestive, however, is that the 1966 point also lies above the line and is the first point for any of the "sixties" so to do. Moreover, to push the possible "take-off point" still further into the past, observe that the growth—at an increasing rate—from 1964 to 1967 far exceeded the experienced in any preceding three-year interval:

Year	M	ΔM (3 years)
1952	73	
1955	1203	1130
1958	2330	1127
1961	3205	875
1964	4159	954
1967	5963	1804

Clearly the latest three-yearly increment of 1804 is unprecedented. Putting the yearly increments of 1964–1965, 1965–1966, and 1966–1967 on a percentage basis, one has respective growth rates of about 10%, 12%, and 16% for the three years, where, in contrast, an exponential fit would show a constant rate, and a linear fit would give declining values.

Well, it would be perilous and premature to make too much of our recent experience as a guide to future and probably non-linear growth patterns, but we are also led to question the likelihood of a future linear pattern by looking at the percentage growth rates it would imply. Consider, for example, the values of

$$\frac{344}{344Y + 182}.$$

For 1968 (Y = 16) one is already down to 6%, a value sometimes cited as minimal for thriving economies, etc. Moreover, by the end of the century, one is down to about 2%—roughly the rate of increase (currently) of the American population.

The Market for Future Growth

Although it would be extremely difficult to make a good estimate of our "market" without a more precise specification of our "product," it is interesting to look at some estimating relations that may yield bounds or gross approximations.

One approach, using some observations of George Morgenthaler, is to look at the market for studies. Considering the fees that a homeowner pays for professional

advice when he purchases a house, that an industrial concern pays for studies of plant location/design, that a government agency pays for a study of competing programs/designs before it makes its decision, etc., Morgenthaler concludes:

"Thus we find a trade-off study cost of about .1% to 1% of the value of the resources involved in the decision."

He also quotes Brockway McMillan to the effect that "10 percent or 5 percent of the amount at risk" in a large space agency or defense department program is not too much to spend in an initial study of relevant alternatives.

These arguments suggest that the interest in a cost-effectiveness study may vary with the risk involved in decision, and factors ranging from .1% to 10% should be applied carefully, in individual cases, using some knowledge of special circumstances. But one may, for present purposes, use such factors with some boldness to estimate what the total market for studies might be. McMillan's "10 percent" is probably most pertinent to high risk programs, and would seem too large to apply uniformly to all governmental or industrial programs. Suppose, however, that one looks at Morgenthaler's smaller factors, and what they would imply if applied to a total economy on the order of 800 billion dollars GNP. This would give a sum of from 800 million dollars to 8 billion dollars spent on "studies" in one year. To convert these sums to people, one might, very roughly, use about $25,000 per person to give on the order of 30,000 to 300,000 people.

Now, one asks, what fractions of these people are candidates for an operations research society. If this fraction were one-third, then we would have a market—from "study performers"—of from 10,000 to 100,000 members.

A different basis for estimate arises from the question; What portion of the population at large should be operations researchers, or operations research society members? This way of putting the question may seem particularly pertinent as/if automation "takes over" and workers tend generally to become service personnel, consultants, "hand-holders," etc. Already, one expresses medical employment in terms of people/doctor. Using this basis, one observes first that in the U. S. today slightly less than one person in 30,000 is a member of ORSA. If the linear expression $M = 344Y + 182$ held in the future, while the present exponential growth rate of the United States continued, the fraction would increase to slightly less than one person in 20,000 by about the end of the century, after which it would decline.

There are other, and probably better, approaches that should be explored. One member observes:

"The Conference Board of Mathematical Sciences is currently completing a study of mathematical manpower resources and training as of the moment and is making projections of trends into the near future. I think your committee should have access to this material to answer the questions about growth rate of OR oriented individuals and how fast ORSA membership should grow."

Contact with the Conference Board has established that few useful data are now available, but this source, as well as the Bureau of Labor Statistics may be useful in the future.

Factors Influencing Future Growth

Among the factors which can significantly influence the future growth of ORSA is its own membership policy. If emphasis is placed on considerations that restrict

membership, then growth can be expected to be small, especially in the absence of a "membership drive" to "capture" a large fraction of those who can meet the restrictive conditions. On the other hand, emphasis on a large membership might well lead to considerable growth. (Even if many restrictions were retained, a sudden emphasis on acquiring as members a large fraction of those who meet the conditions could lead to a short term spurt in growth.)

As one critic points out, the society seems to have used membership standards as a means of implementing the second (of its four) basic initial purposes, the one that relates to the enhancement of "professional standards of competence." By making membership standards high, of course, one can increase the average professional competence of the members. In practice it appears that beyond the stated qualifications (required evidence of ability to do "good" OR to be supplied in connection with membership applications) there is yet another important mechanism: Machol observes that limitations in the rate of processing applications have led to a "plateau" in membership growth rates.

In other specialties, as one scholarly member reminds us, such as law, medicine, engineering, "licensing" as evidence of competence has become a function of the State, or institution which has enforcing powers, though professional societies have played an important role in instituting present procedures and continue today to supply valuable advice. Thus ORSA has a role to play, if it so wills, in recommending and implementing procedures for the identification, certification, etc., of professional competence.

It is important to note that ORSA still would have significant options with respect to membership policy even if the States were to license practicing operations researchers. On the one hand, ORSA could restrict members, or one class of members, to the especially competent, honored, senior, etc., thus creating a kind of "club" or "academy." On the other hand, it would be possible to open the doors to a wide membership, including many "non-practicing" workers, such as management, specialists of other disciplines, students, etc.

One way in which these membership policies and questions impinge on other issues is illustrated by the concern with society responsibilities for "speaking out" on important national problems where OR has something to offer. Who is to speak out, or at least to have the opportunity to help decide what the society says officially, all members or only a restricted class? Moreover, if the society finds itself in the position of "lobbying for good," will it thereby have an incentive to enlarge its membership, so as to speak with a larger voice, or to restrict its membership, so as to speak with a sharper, more authoritative voice?

Membership Criteria and Composition

At present the ORSA membership is comprised of two classes: Associate Members and Full Members. Any person interested in Operations Research may become an Associate Member. A range of alternative criteria is set forth for Full Membership; these criteria are applied by the Membership Committee. To become a Full Member, an applicant must receive favorable votes of the majority of that Committee prior to a final vote by the Council. Normally, two full members of ORSA are required as references of eligibility for each candidate.

In considering alternative membership criteria to select a set that will best

serve ORSA's long range objectives, there are several important questions. Are the present criteria for full membership adequate? Are they too general or flexible? Are they being applied in a manner that will help assure a high quality membership, for example, one capable of providing effective professional response to public issues as Dr. Ancker suggests? Another point to consider is that employers respect ORSA membership the same as they do other professional society memberships. Do we, as a whole, deserve this respect? If not, what can we do to assure that in the future ORSA membership is at least an indicator (not guarantee) that a person is qualified to do OR?

Is it necessary or does it serve the best interest of the Society to have an "Associate" category of membership? Should this category be eliminated in favor of a single membership category? If so, how would this affect membership criteria? If a large membership serves the best interest of the Society, then the Associate category should be retained. A large membership does help to insure the financial success of our meetings and also a channel for keeping a larger segment of the public currently informed of the value and achievements of OR as a profession. On the other hand, merging of the present Associate category ("anyone can join") with the Full Membership unquestionably would result in down-grading the over-all professional quality and hence status of the (full) Membership.

Should ORSA create a special recognition category (e.g., Distinguished Member) to which Members who contribute outstandingly to the field of the Operations Research might be elected? Such categories exist in a number of other professional societies for example: American Statistical Association, American Astronautical Society, American Psychological Association, American Society of Mechanical Engineers and The Institute of Mathematical Statistics. The common criteria specified by these societies is that the member so recommended will be one who has made a direct and significant contribution to his professional field (in our case, OR). If ORSA is to be a high quality professional society—one say that might be called upon to provide professional advice as a public service—should it not also provide a means of bestowing special recognition to those who make outstanding contributions in such endeavors, and also those who make distinguished contributions to the field itself?

The alternative criteria and classes of ORSA membership discussed above are summarized in the following table:

	Continue Current Rules	Alternatives A	B	C	D
Associate Membership Open to Anyone	X	X	X		
Full Membership Criteria:				X	X
Not So Rigid	X		X		
			or		
More Rigid		X	X		
Distinguished Membership			X	X	

Under alternative A, the action would be to develop more rigid requirements for full membership and/or more rigidly enforce the criteria. Alternatives B and C

would add a category for use in honoring members making distinctive contributions to OR. Alternative B would retain the Associate class (easier to process applications of new joiners) while alternative C would, in view of having provided a means for honoring distinguished members, adopt a less rigid attitude regarding the membership at large and in so doing merge the associate and full member classes. Alternative D would also open the membership to larger numbers but provide no distinguished member class. Accordingly, if ORSA wants to strengthen its professional status in the future, alternatives A and B are good choices. If it does not, current rules or D are appropriate choices. Alternative C is sort of a compromise.

Relation of the Society to Various Academic Disciplines

The question of "responsibility," as it relates to membership, also raises questions concerning the relation of the society to various academic disciplines. If one of the important responsibilities, as has been suggested, concerns the ethics of the practitioner, especially as this relates to his role in advising on important decisions, then this leads to a distinction between an "applied" worker, who is in at the crunch of decision making, and a solely "theoretical" worker, who is interested, let us say, only in devising algorithms for mathematical programming problems that arise in connection (possibly vague) with resource allocation problems. Such a distinction might be quite unimportant in many contexts but essential in deciding on membership policies as related to instituting an effective procedure to facilitate the society's "speaking out" on important issues.

There is another way, perhaps more direct and important, in which the relation of academic disciplines to OR, enters. This is in connection with the determination of the "gross market" itself, and certainly concerns mathematics. In interpreting the data of the Conference Board of Mathematical Sciences, once available, it will be important to distinguish between a view of OR as that subset of mathematics concerned with resource allocation problems and a view of OR as a profession/science that helps to structure sprawling and previously unstructured problem areas as an essential aid to management and planning.

The same distinction impinges on education policy for OR. There is the old question: Is OR "teachable?" Or, since many universities are presumably teaching something in their "OR Departments," the question might be rephrased as "Is what is taught, OR."

The Possibility of Merger

Yet another issue that hinges on much the same distinction is that of merger. This subject has most frequently been mentioned in connection with TIMS, and many would presumably agree with one member's observation that distinctions between ORSA and TIMS are largely "semantic." Yet what of SIAM? Or of the research that OR has rediscovered a lot that was already known in statistics? Or of Alain Enthoven's expressed preference for economists as systems analysis because they naturally think of alternatives? It would appear that ORSA has reason to resist identification with any one established discipline (and thus to regret the recent Civil Service Commission decision to place OR in the Mathematical Services) but also should explore the possibility and desirability of a merger with TIMS. This particular issue appears worthy of research on an ad hoc basis.

Other Impacts of Membership Size and Composition

There are, of course, many obvious "practical" considerations where the size and composition of membership impinges on the work of such standing committees as those that deal with meetings and publications. A projection of the linear growth rate shows some 17,000 members by the end of the century, but an exponential (or hyper-exponential) rate could lead to 50,000 or even over 100,000 members. Would our meetings then be conducted on closed circuit TV, or be nationally televised on commercial TV, or, at the other extreme, attract only a hard core of the membership who display either "individual initiative" or the "dominance of a central group?" Or would only individual sections have meetings? Similarly, we may ask if our publications will be generally interesting or only intelligible to hyper-specialists, or if different journals will address different segments of the society.

APPENDIX

The Committee has received advice from many sources. Expectedly, many questions were posed by more than one source, either in identical form or nearly so. We have compiled and edited these and present them in the following list. Obviously, many questions are related. The categories are arbitrary and no claim of completeness is made. However, we do feel the list is a useful and valid starting point for new inquiries and is representative of the thinking of many thoughtful and concerned people.

I. *Organization, Management and Purpose*

1. Does ORSA need Long Range Planning?
2. Should ORSA systematize its budgeting?
3. Does the financial structure of ORSA need revamping?
4. Should ORSA be a professional or a scientific society?
5. Should ORSA encourage the development of its Sections (technical, geographic or student) in a planned and systematic manner?
6. Should ORSA seek mergers with other related organizations (e.g. TIMS, SIAM, MORS, WORC (to become Washington Section))? This involves the question of dispersion, splintering and dissipation of effectiveness.

II. *Meetings*

1. Should ORSA aggressively pursue joint meetings with other societies? (e.g. AIAA, AIIE, etc?)
2. Should ORSA meetings be critically appraised from a scientific viewpoint?
3. Should the Society undertake Classified Meetings?
4. Should there be any changes in the frequency and type of ORSA meetings?

III. *Publications*

1. Does ORSA (or its Sections) need new or different publications?
2. Should the publication(s) stress applications, theory or both?
3. Should OPERATIONS RESEARCH be more mathematical? less? more empirical? Is it meeting the needs of all sectors?
4. Should ORSA published papers be critically appraised from a scientific viewpoint?

IV. *Education*

1. Should ORSA greatly increase its efforts to stimulate education and training of OR scientists?
2. Should ORSA (or its Sections) set suggested requirements for education in OR?

V. *Public Responsibility*

1. Should the Society assume responsibility for initiating cross-fertilization with adjacent areas of Science and Technology?
2. Should ORSA develop a code of ethics for the profession?
3. Should ORSA (similar to the Actuary Society) attempt to set up a stiff requirement for recognition of entitlement to the name "Operations Analyst"?
4. Should ORSA become a standards setting organization—(e.g. notation and nomenclature in Queuing Theory?—or GS ratings in Civil Service)?

VI. *Miscellaneous*

1. Should ORSA seek ways of recognizing outstanding achievement in addition to the Lanchester Prize?
2. Should the Society encourage release of Company proprietary information which is of general interest?

PAYMENT OF BILLS

ORSA members resident in England are informed that, effective as of the present, the Operational Research Society (UK) will no longer accept dues payments for ORSA members. All ORSA dues will be payable only to the Business Office, ORSA, 428 East Preston Street, Baltimore, Maryland 21202.

ORSA VISITING LECTURESHIP PROGRAM

ORSA is continuing its Visiting Lectureship Program for the 1968–69 academic year with sponsorship from the National Science Foundation. The program has the following aims: to stimulate existing operations research courses and programs in universities and colleges which do not at present offer degrees in operations research; to aid and motivate the starting of new operations research courses and curricula; to motivate able students towards careers in operations research; to provide education and information on the nature and scope of operations research, and to provide information and advice to students, student counselors and faculty members on the availability of advanced training in operations research.

Lecturers will not only present formal lectures, but will be available to discuss teaching problems and curricula matters with members of the staff and to advise students on future opportunities in study and employment.

Anyone interested in further information should write:

Visiting Lectureship Series in Operations Research,
% Professor J. R. Borsting,
Department of Operations Analysis,
Naval Postgraduate School,
Monterey, California 93940

OFFICERS OF THE WESTERN SECTION OF ORSA FOR 1968

Chairman:	Joseph F. McCloskey
Vice Chairman:	Richard E. Trueman
Secretary/Treasurer:	Peter W. Zehna
Past Chairman (immediate):	Arthur C. Christman, Jr.

THE INSTITUTE OF MANAGEMENT SCIENCES

The Institute of Management Sciences, in response to a number of inquiries from various corporations has introduced a program of institutional membership It is hoped that it will result in the many firms which have Operations Research/ Management Science activities, taking a more active role in TIMS affairs and programs, thus making TIMS more responsive to the professional community. Also, it would permit TIMS to more adequately support various educational and publication programs now in effect or in various planning stages. The Institutional member may nominate one individual to serve as a regular member of TIMS. Both the Institution and their Representative will receive Management Science, the TIMS Monthly Journal. Institutional members will be duly acknowledged in the TIMS Journals. These institutional memberships will cost $250.00. Accordingly, if your company is interested in joining others in participating in this program, could you please send a check in the amount of $250.00 made out to The Institute of Management Sciences. Please mail it to the attention of HERBERT HALBRECHT, TIMS, P.O. Box 6112, Providence, R. I. 02904.

HELLENIC OPERATIONAL RESEARCH SOCIETY

The Hellenic Operational Research Society (HELORS) organises an international meeting authorized by IFORS in Athens, Greece, from 4 to 8 November on the subject: "Operational Research in Electrical Power Systems". Deadlines fixed in the previous announcement are changed as follows: In the case of submitting papers: summary till 20 July this year; the definitive paper till 20 September this year. In the case of not submitting papers any time till the time of the conference. Participation letters or cards or for any inquiry should be sent to the following address:

HELORS Conference O.R.E.P.S.
GENERAL R. SPANOYANNAKIS
% Productivity Center
Kapodistriou 28
Athens 147
GREECE

A tourist program will be organised, and particularly a one-day excursion to Delphi and a one-day excursion to Corinthe, Mykinai, Epidaure. During the conference itself, most part of afternoons will be free, which will allow the participants to visit Athens and surrounding sites.

Fees for participants will be as follows: For participants belonging to organizations not being collective members of O.R. Societies $70. For participants belonging to organizations being collective members of O.R. Societies $60. For

participants not sponsored by an organization and not member of O.R. Societies $40. For participants not sponsored by an organization and member of O.R. Societies $30.

PERSONAL ITEMS

WILLIAM H. EVERS has been promoted to Manager of Operations Research, Corporate Headquarters, IBM, Armonk, New York.

IRVING B. GOODMAN has joined the National Resource Analysis Center, Office of Emergency Planning, Executive Office of the President.

EDWARD G. RODGERS, Assistant Professor of Quantitative Methods at Georgia State College in Atlanta, has been elected Chairman of the Southeast Region of the Institute of Management Sciences.

GERALD M. HOFFMAN has been appointed Manager, Operations Research, Standard Oil Company (Indiana), 910 South Michigan Avenue, Chicago, Illinois.

RICHARD F. BARTON, Professor of Management, Texas Technological College, Lubbock, Texas has been named director of the Office of Planning and Analyses at the college.

VERNON E. PALMOUR has joined the staff of Westat Research, Inc. in Bethesda, Maryland as a Senior Research Analyst.

H. N. LADEN has been appointed Assistant Vice President-Research of the Chesapeake & Ohio-Baltimore & Ohio railroads.